Learning to Interpret a Disjunction

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Abstract

At first glance, children's word learning appears to be mostly a problem of learning words like *dog* and *run*. However, it is small words like *and* and *or* that enable the construction of complex combinatorial language. How do children learn the meaning of these function words? Using transcripts of parent-child interactions, we investigate the cues in child-directed speech that can inform the interpretation and acquisition of the connective *or* which has a particularly challenging semantics. Study 1 finds that, despite its low overall frequency, children can use *or* close to parents' rate by age 4, in some speech acts. Study 2 uses annotations of a subset of parent-child interactions to show that disjunctions in child-directed speech are accompanied by reliable cues to the correct interpretation (exclusive vs. inclusive). We present a decision-tree model that learns from a handful of annotated examples to correctly predict the interpretation of a disjunction. These studies suggest that conceptual and prosodic cues in child-directed speech can provide information for the acquisition of functional categories like disjunction.

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Learning to Interpret a Disjunction

Introduction

Word learning is commonly construed as the process of detecting a word form, hypothesizing candidate meanings for that word form, and mapping it to the right meaning (**???**). For example, a father holding a baby may point to a squirrel and say "look at the squirrel!" Assuming that the baby understands the phrase "look at the", she needs to detect the novel word *squirrel*, consider some potential referents for it (e.g tree, chair, leaf, squirrel, etc.) and select the right referent among them. The problem of finding the right meaning among a set of candidate word meanings is called "the mapping problem". and plays a central role in using the available cues, in this case the father's pointing. While there has been a lot of research on cues and mechanisms that help children's acquisition of content words such as *squirrel*, *red*, and *run*,

cues and mechanisms involved in learning function words such as *and* and *or* have remained a major challenge. In this study, we focus on the disjunction word *or* and provide a novel learning account that uses salient cues to learn the interpretations of disjunction in English.

How do children learn the meaning of disjunction

Previous Studies

To our knowledge, only one study has looked at spontaneous productions of *and* and *or* in parents' and children's speech. Morris (2008) investigated children between the ages of 2;0 and 5;0, using 240 transcriptions of audiotaped exchanges obtained from the CHILDES database. Each connective was analyzed with respect to its frequency, sentence type, and meaning (or use). The study found that overall, *and* was approximately 12.8 times more

likely to be produced than *or*. The connective *and* appeared predominantly in statements (more than 90% of the time) while *or* was most common in questions (more than 85% of the time). Children started producing *and* at 2 years and *or* at 2.5 years of age.

Regarding the meaning of the connectives, Morris (2008) adopted a usage-based (item-based) approach (Levy & Nelson, 1994; Tomasello, 2003) and predicted that children start producing connectives with a single "core meaning" (also referred to as "use" or "communicative function"). He predicted that the core meaning mirrors the most frequent usage/meaning of the connective in child-directed speech. Children acquire the less frequent meanings of the connectives as they grow older. He found that children started producing *and* as conjunction at 2, and *or* as exclusive disjunction at 2.5 years of age. In line with the predictions of the usage-based account, he found that these two meanings are the most frequent meanings in parents' speech. For disjunction, 75-80% of the *or*-examples children heard recevied an exclusive interpretation. Finally, as children grew older, they started using connectives to convey additional meanings such as inclusive disjunction for *or* and temporal conjunction for *and*. However, the inclusive use of *or* was extremely rare in adults, and children barely produced it even at age 5. Morris (2008) argued that the development of connectives conforms to the predictions of a usage-based account and that in the first five years of children's development, the (core) meaning of disjunction is exclusive.

However, a series of experimental studies have found that preschool children are more likely to interpret *or* as inclusive in a variety of linguistic contexts such as negative sentences (Crain, Gualmini, & Meroni, 2000), conditional sentences (Gualmini, Crain, & Meroni, 2000), restriction and nuclear scope of the universal quantifier *every* (Chierchia, Crain, Guasti, Gualmini, & Meroni, 2001; Chierchia et al., 2004), nuclear scope of the negative quantifier *none* (Gualmini & Crain, 2002), restriction and nuclear scope of *not every* (Notley et al., 2012a), and prepositional phrases headed by *before* (Notley et al., 2012b). These studies almost unanimously claim that at least in declarative sentences, the inclusive interpretation

of *or* emerges earlier than the exclusive interpretation.

The findings of these studies as well as those of Morris (2008) give rise to what we call "the paradox of learning disjunction". Given Morris (2008)'s finding that the majority of *or* examples children hear are exclusive, how can children learn to interpret it as inclusive? One way to addresses this paradox is logical nativism (Crain, 2012; Crain & Khlentzos, 2008, 2010). This approach assumes that the language faculty contains information regarding what connective meanings are allowed for connective words crosslinguistically. Crain (2012) considered it unlikely that children learn the meaning of *or* from the examples they hear in adult usage. Instead, he argued that children rely on an innate knowledge that the meaning of disjunction words in natural languages must be inclusive. In other words, upon hearing a connective word, children consider inclusive disjunction as a viable candidate for its meaning but not exclusive disjunction. In this account, the exclusive interpretation emerges as part of children's pragmatic development after they have mastered the inclusive semantics of disjunction.

While logical nativism addresses the paradox of learning disjunction, it does not provide an explanation for cases where children interpret disjunction as exclusive. Morris (2008) reported that in his study, the vast majority of children used *or* in its exclusive sense. This is not expected if preschool children consider disjunction to be inclusive. Second, other experimental studies, especially those testing disjunction in commands, find that preschool children interpret it as exclusive (Braine & Rumain, 1981; Johansson & Sjolin, 1975). For example, in response to a command such as "give me the doll or the dog", children as young as three- and four-years-old give one of the objects and not both. In its current version, the nativist account does not provide any explanation for such cases.

Figure 1 summarizes the usage-based and nativist approaches to the acquisition of disjunction. The major difference between them is their assumptions on the learners' semantic hypothesis space for *or*. The usage-based account considers a wide array of

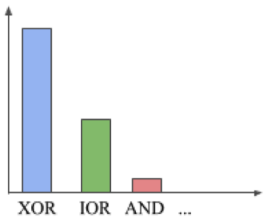
<table>
<tr><th>Learning Accounts of Disjunction</th><th>Binary Connective Hypothesis Space</th><th>Input Frequency for or</th><th>Early Mapping</th></tr>
<tr><td>Usage-Based Account
(Morris 2008)</td><td>{XOR, IOR, IF, AND,
$AND_{temporal}$,
$AND_{explanatory}$,
$AND_{extension}$, ...}</td><td rowspan="2"> 
</td><td>“or” → XOR</td></tr>
<tr><td>Logical Nativism
(Crain 2012)</td><td>{IOR, AND, IF}</td><td>“or” → IOR</td></tr>
</table>

Figure 1. Summary of the usage-based and nativist approaches to the acquisition of disjunction.

meanings to be available for mapping, including different flavors of conjunction such as “temporal conjunction” (e.g. Bob pressed the key and (then) the door opened) and “explanatory conjunction”. The nativist account limits the hypothesis space to binary logical connectives, more specifically to those commonly used in standard propositional logic: inclusive disjunction, conjunction, and material implication. Both accounts agree that the input favors the exclusive interpretation of disjunction. The usage-based account concludes that children’s early mappings mirror this input. The nativist account suggests that innate biases towards the inclusive meaning and against the exclusive interpretation result in an inclusive semantics for *or* in children’s early mappings.

Current Study

In this study, we provide an alternative solution to the paradox of learning disjunction. The main claim of this paper is that children may learn to interpret *or*– for example as exclusive or inclusive – using the salient cues that accompany it in the input. We support this hypothesis using three studies. In the first study, we investigate the distribution of *and* and *or* in parent-child interactions to address the following basic questions: how often do children hear or produce *or*? when do they start producing it? Using a large corpus of parent-child interactions, we found that children hear 1-2 examples of *or* in every thousand words parents produce. They start producing it themselves between 18-30 months, and by 42 months they reach a rate of one *or* per thousand words. In study 2, we ask: what interpretations can *or* have in child-directed speech? We annotated examples of *or* and found that its most likely interpretation is exclusive disjunction, as Morris (2008) had concluded. However, we also found that exclusive interpretations correlated strongly with two cues: rise-fall prosody, and logically inconsistent propositions connected by *or*. In the absence of these cues, *or* was most likely inclusive. In our third study, we ask if it is possible to learn the interpreation of *or* from these cues. Using the annotation data of study 2 and a supervised learning task, we showed that a decision-tree classifer can use prosody and consistency of propositions to predict its interpretation with high accuracy.

Based on the results of our studies, we propose a new account for children's acquisition of disjunction. Figure 2 shows the summary of this account which we call cue-based context-dependent mapping. It is inspired by the usage-based and nativist accounts of disjunction and shares many of their insights. Similar to the nativist account, we assume that the semantic hypothesis space includes binary logical relations. However, we do not limit the hypothesis space further and do not bias the learning towards the inclusive meaning. We will show that the input can achieve this. Similar to usage based proposals, our account relies on the structure of the input to distinguish between exclusive and inclusive uses of disjunction.

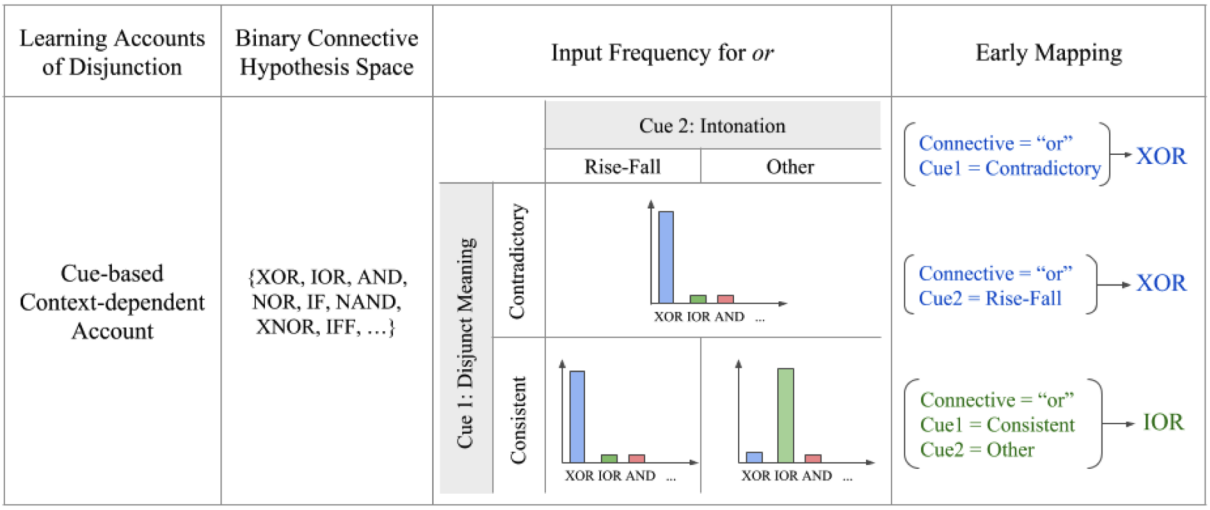


Figure 2. Summary of the usage-based and nativist approaches to the acquisition of disjunction.

We also map more complex constructions to meanings rather than the word *or* directly. The learner can later extract commonalities across these mappings and extract a core semantics for a particular word. However, the early mappings do not have any core meaning as opposed to what the usage-based account of Morris (2008) proposes. The major point of departure from previous accounts is the mechanism of learning. While in pervious accounts the most frequent meaning in the input was mapped to the connective word directly, in our account the input is partitioned or broken down by a set of salient cues that designate the context of use. Mapping is done based on the cues that accompany the connective word.

Study 1: Production of "or" in parent-child interactions

In our first study, we looked at the frequencies of *and* and *or* in a corpus of parent-child interactions (CHILDES) with 14,159,609 words. This is a considerably larger corpus than previously used.

Methods

For samples of parents' and children's speech, we used the online database childes-db and its associated R programming package `childesr` (Sanchez et al., 2018). Childes-db is an online interface to the child language components of TalkBank, namely CHILDES (MacWhinney, 2000) and PhonBank. Two collections of corpora were selected: English-North America and English-UK. All word tokens were tagged for the following information: 1. The speaker role (mother, father, child), 2. the age of the child when the word was produced, 3. the type of the utterance the word appeared in (declarative, question, imperative, other), and 4. whether the word was *and*, *or*, or neither.

Exclusion Criteria. First, tokens were coded as unintelligible were excluded (N = 290,119). Second, tokens that had missing information on children's age were excluded (N = 1,042,478). Third, tokens outside the age range of 1 to 6 years were excluded (N = 686,870). We were interested in the 1 to 6 years old age range and there was not much data outside this age range. The collection contained the speech of 504 children and their parents after the exclusions.

Procedure. Each token was marked for the utterance type that the token appeared in. This study grouped utterance types into four main categories: "declarative", "question", "imperative", and "other". Utterance type categorization followed the convention used in the TalkBank manual. The utterance types are similar to sentence types (declarative, interrogative, imperative) with one exception: the category "question" consists of

interrogatives as well as rising declaratives (i.e. declaratives with rising question intonation). In the transcripts, declaratives are marked with a period, questions with a question mark, and imperatives with an exclamation mark. It is important to note that the manual also provides terminators for special-type utterances. Among the special type utterances, this study included the following in the category "questions": trailing off of a question, question with exclamation, interruption of a question, and self-interrupted question. The category imperatives also included "emphatic imperatives". The rest of the special type utterances such as "interruptions" and "trailing off" were included in the category "other".

Results

Overall, *and* was about 10 times more likely to occur in parents' speech than *or*. More specifically, *and* occurred 15 times and *or* only 1.5 times per 1000 words. Children produced *and* at the same rate as their parents but produced *or* at a considerably lower rate, only 0.5 per thousand (Figure 3, Left). The developmental trend showed that between 12 to 72 months, production of *and* in parents' speech varied between 10 to 20 per thousand words (Figure 3, Right). Children started producing *and* between 12 and 18 months, and showed a sharp increase in their production until they reached the parent level between 30 to 36 months of age. Their productions stayed close to the parents' production level between 36 and 72 months, possibly surpassing them at 60 months – although due to the small amount of data after 60 months we should be cautious with our interpretation of the trend there. The production of *or* for parents was 1 to 2 per thousand words. Children started producing *or* between 18 to 30 months, steadily increasing their productions until they got close to 1 *or* per thousand words at 48 months (4 years). Their productions plateaued and stayed at this rate until 72 months (6 years).

Children's productions of *or* was different from their production of *and* and parents' production of *or*. Children started producing *or* around 6 months later than they started

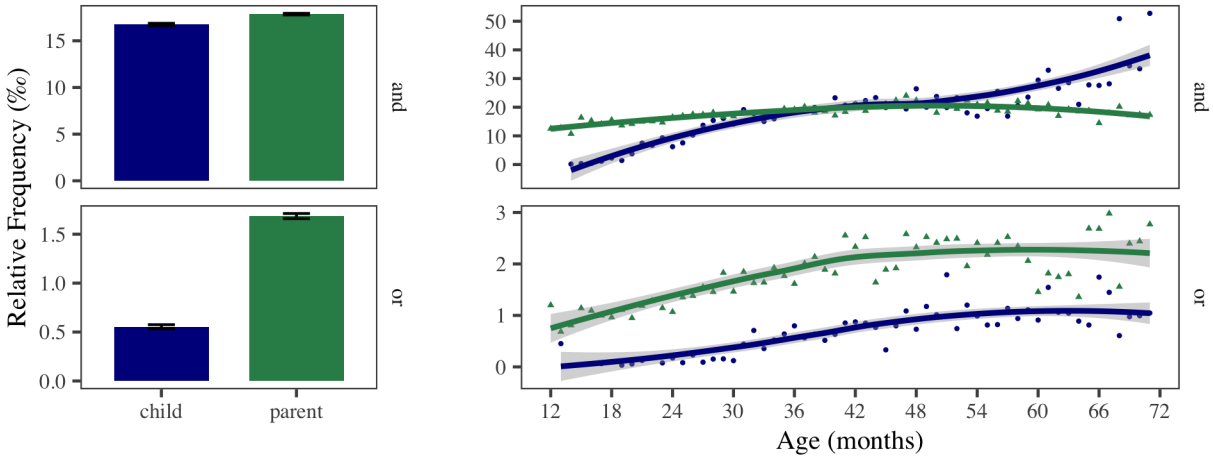


Figure 3. Left: The relative frequency of *and/or* (per mille) in the speech of parents and children. 95% binomial proportion confidence intervals calculated using Agresti-Coull's approximate method. Right: The monthly relative frequency of *and/or* in parents and children's speech between 12 and 72 months (1-6 years).

with *and*. Second, while children's *and* productions showed a steep rise over a year and reached the parent level around 30 months, their *or* productions rose slowly and did not reach the parent level even at 6 years of age. What factors cause these differences? We consider three possibilities here: frequency, conceptual complexity, and usage.

First, *and* is a far more frequent connective than *or*. Goodman, Dale, and Li (2008) argue that within the same syntactic category, words with higher frequency in child-directed speech are acquired earlier. The conjunction word *and* is at least 10 times more likely to occur than *or* so earlier acquisition of *and* is consistent with the effect of frequency on age of acquisition. Second, research on concept attainment has suggested that the concept of conjunction is easier to conjure and possibly acquire than the concept of disjunction. In experiments that participants are asked to detect the pattern of classification in some cards, they can detect a conjunctive classification faster than a disjunctive one (Neisser & Weene, 1962). Therefore, it is possible that children discover the concept that corresponds to the meaning of *and* faster and start to produce it earlier, but they need more time to attain the

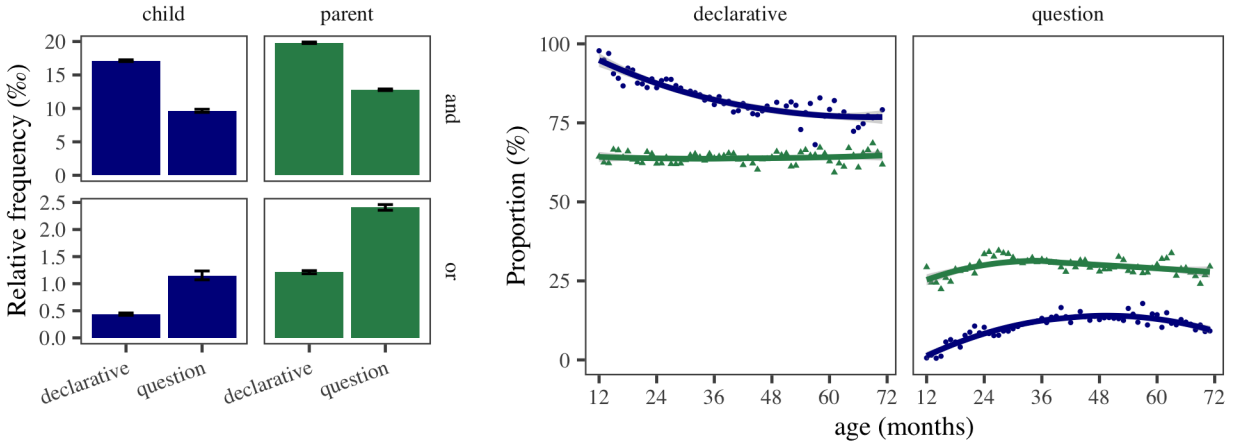


Figure 4. Left: Relative frequency of *and/or* (per mille) in declaratives, imperatives, and interrogatives for parents and children. Right: Percentage of declaratives to questions in parent-child interactions by age.

concept corresponding to the meaning of *or*.

A third possibility is that the developmental difference between *and* and *or* is at least partly due to their different usages. Parent-child interactions are not symmetrical and what parents would like to communicate to children is different from what children would like to communicate to parents. This asymmetry can result in different distribution of speech acts between parents and children and consequently functional elements that constitute them. Here we present evidence that suggests *or* is affected in this way.

First, we found that *or* was more likely to occur in questions than in declaratives (Figure 4, Left). This is in contrast to *and* which was more likely to occur in declaratives. Second, parents asked more questions from children than children did from parents, and children produced more declaratives than parents (Figure 4, Right). In fact, questions had their own developmental trajectory, emerging in the second year of children's lives and reaching a relatively constant rate of about 15% of children's utterances in their fourth year. However, parents produce a constant rate of questions which is about 25% of their

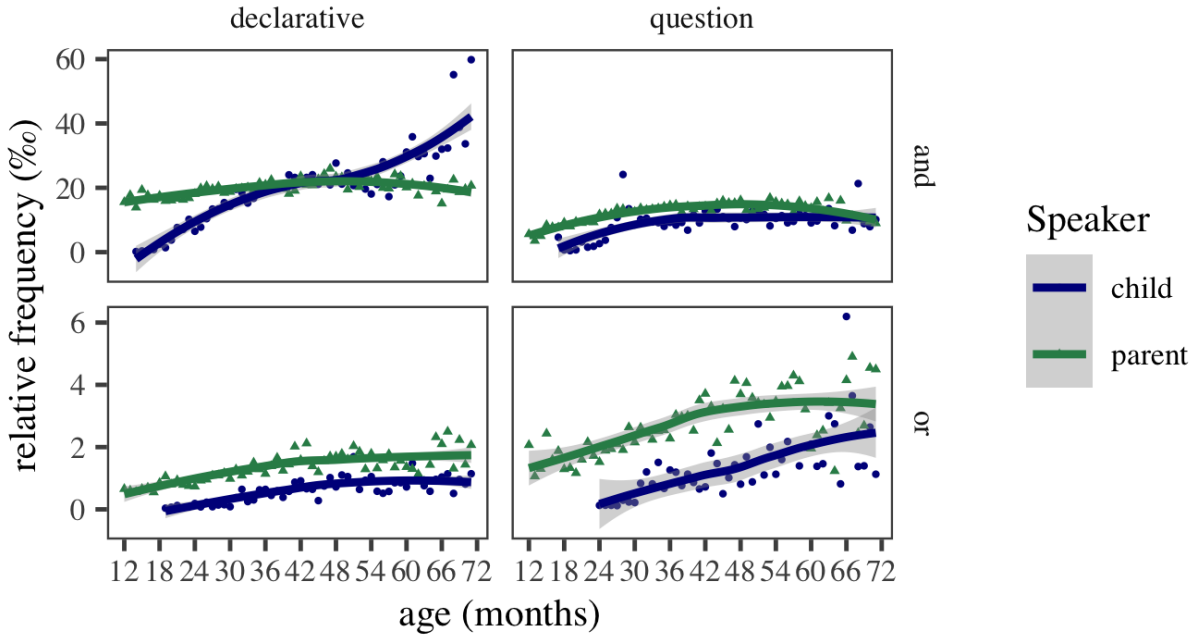


Figure 5. Relative frequency of *and/or* in declaratives and questions for parents and childern between the child-age of 12 and 72 months (1-6 years).

utterances. Therefore, parent-child interaction provides more opportunities for parents to ask questions and produce *or*, than children.

Figure 5 shows the developmental trends for the relative frequencies of *and* and *or* in questions and declaratives. Comparing *and* in declaratives and questions, we see that the onset of *and* productions were slightly delayed for questions. But in both declaratives and questions, *and* productions reached the parent level around 30 months (2.5 years). For *or*, we see a similar delay in questions compared to declaratives. Children started producing *or* in declaratives at around 18 months but they started producing *or* in questions at 24 months. Production of *or* increased in both declaratives and questions until it reached a constant rate in declaratives between 48 and 72 months. The relative frequency of *or* in questions continued to rise until 60 months. Comparing Figure 3 and 5, children were closer to the adult rate of production in declaratives than questions.

Table 1

Estimated cofficients for the linear model with children's age, speaker (child vs. parent), utterance type (declarative vs. question), and their interactions as predictors. Relative frequency of disjunction produciton was the dependent variable.

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
age	0.02	0.01	3.54	0.00
question	-0.77	0.39	-1.96	0.05
parent	0.72	0.32	2.24	0.03
age*question	0.03	0.01	3.96	0.00
age*parent	0.00	0.01	0.21	0.83
question*parent	1.40	0.48	2.91	0.00
age*question*parent	-0.01	0.01	-1.30	0.20

To test these observations more formally, we used a linear regression model with the relative frequency of *or* as the dependent variable and children's age, speaker (child vs. parent), utterance type (declarative vs. question), and their interactions as predictors. The intercept was set to children's productions in declaratives. Table 1 presents the coefficient estimates of the model. Overall, the model suggests that parents and children produced more *or* as children grew older and parents produced more instances of *or* than children. However, the increase in production of *or* was more steep in questions. The largest significant effect was the interaction of speaker and utterance type. Parents produced disjunctions more frequently in quesions than in declaratives. These results are consistent with the hypothesis that frequency and distribution of *or* is partly affected by the development of questions in parent-child interactions.

Conclusion

In a large-scale quantitative analysis of parents and children's productions of *and* and *or*, we found that children started producing *and* in the second year of their lives, and

quickly reached their parents' rate of production by two and a half. Their production of disjunction was delayed by six months on average: they started producing *or* between 1.5 and 2.5 years of age, and around 3.5 years, they reached a relatively constant rate of production below that of their parents. We considered three possible causes for disjunction's delay and lower rate of production: the higher frequency of *and*, the conceptual and mapping complexity of *or*, and the asymmetry in speech acts produced by parents and children. We provided evidence for the last cause. We showed that parents produced more questions than children, and that *or* was more likelly to occur in questions. Therefore, parents' speech contained more *or* partly due to the fact that parents asked more questions.

Study 2: Interpretations of disjunction in child-directed speech

In this study we selected a subset of connective examples in child-directed speech from study 1 to closely examine the interpretations they recieve. Research in formal semantics has shown that the interpretation of disjunction depends on several factors including prosody (Pruitt & Roelofsen, 2013), logical consistency of the propositions being connected (Geurts, 2006), pragmatic and scalar reasoning (Grice, 1989). Our main claim here is that in child-directed speech, exclusive interpretations of *or* correlate with rise-fall prosody and logically inconsistent propositions. In the absence of these two factors, *or* is most likely "not exclusive".

Methods

This study used the Providence corpus (Demuth, Culbertson, & Alter, 2006) available via the PhonBank section of the TalkBank.org archive. The corpus was chosen because of its relatively dense data on child-directed speech as well as the availability of audio and video recordings that would allow annotators access to the context of the utterance. The corpus

was collected between 2002 and 2005 in Providence, Rhode Island. Table 3 in appendix reports the name, age range, and the number of recording sessions for the children in this study. All children were monolingual English speakers and were followed between the ages of 1 and 4 years. Based on Study 2, this is the age range when children develop their early understanding of *and* and *or*. The corpus contains 364 hours of biweekly hour-long interactions between parents and children.

Exclusion Criteria. We excluded data from Ethan since he was diagnosed with Asperger's Syndrome at age 5. We also excluded all examples found in conversations over the phone, adult-adult conversations, and utterances heard from TV or radio. We did not count such utterances as child-directed speech. We excluded proper names and fixed forms such as "Bread and Circus" (name of a local place) or "trick-or-treat" from the set of examples to be annotated. Such forms could be learned and understood with no actual understanding of the connective meaning. We counted multiple instances of *or* and *and* within the same disjunction/conjunction as one instance. The reasoning was that, in a coordinated structure, the additional occurrences of a connective typically did not alter the annotation categories, and most importantly the interpretation of the coordination. For example, there is almost no difference between "cat, dog, and elephant" versus "cat and dog and elephant" in interpretation. In short, we focused on the "coordinated construction" as a unit rather than on every separate instance of *and* and *or*. Instances of multiple connectives in a coordination were rare in the corpus.

Procedure. All utterances containing *and* and *or* were extracted using the CLAN software and automatically tagged for the following: (1) the name of the child; (2) the transcript address; (3) the speaker of the utterance (father, mother, or child); (4) the child's birth date, and (5) the recording date. Since the focus of the study was mainly on disjunction, we annotated instances of *or* in all the child-directed speech from the earliest examples to the latest ones found. Given that the corpus contained more than 10 times the

number of *and*'s than *or*'s, we randomly sampled 1000 examples of *and* to match 1000 examples of *or*. Here we report the results on 627 examples of *and* and 608 examples of *or*.

Annotation Categories. Every extracted instance of *and* and *or* was manually annotated for 7 categories: connective interpretation, intonation type, utterance type, syntactic level, conceptual consistency, communicative function, and answer type. We briefly explain how each annotation category was defined. Further details and examples are provided in the appendix section.

1. *Connective Interpretation*

This annotation category was the dependent variable of the study. Annotators listened to coordinations such as "A or B" and "A and B", and decided the intended interpretation of the connective with respect to the truth of A and B. We used the sixteen binary connective meanings shown in Figure 6. Annotators were asked to consider the two propositions raised by the coordinated construction, ignoring the connective and functional elements such as negation. Consider the following sentences containing *or*: "Bob plays soccer or tennis" and "Bob doesn't play soccer or tennis". Both discuss the same two propositions: A. Bob playing soccer, and B. Bob playing tennis. However, the functional elements combining these two propositions result in different interpretations with respect to the truth of A and B. In "Bob plays soccer or tennis" which contains a disjunction, the interpretation is that Bob plays one or possibly both sports (IOR). In "Bob doesn't play soccer or tennis" which contains a negation and a disjunction, the interpretation is that Bob plays neither sport (NOR). For connective interpretations, the annotators first reconstructed the coordinated propositions without the connectives or negation and then decided which propositions were implied to be true/false.

2. *Conceptual Consistency*

Propositions stand in complex conceptual relations with each other. For example, have

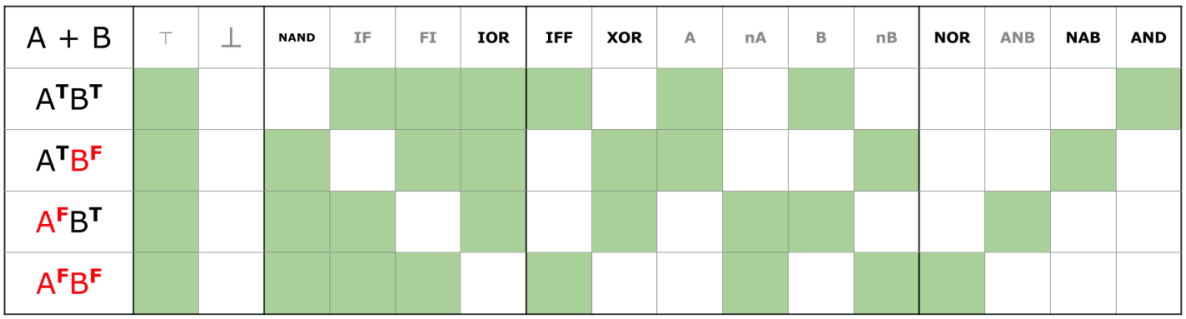


Figure 6. The truth table for the 16 binary logical connectives. The rows represent the set of situations where bot A and B, A, B, or, neither propositions are true. The columns represent the 16 possible connectives and their truth conditions. Green cells represent true situations.

logical, temporal, and causal relation with each other. For conceptual consistency, annotators decided whether the propositions that made up the coordination could be true at the same time or not. If the two propositions could not be true at the same time and resulted in a contradiction, they were marked as inconsistent. Our annotators used the following diagnostic to decide the consistency of the disjuncts: Two disjuncts were marked as inconsistent if replacing the word *or* with *and* produced a contradiction. For example, changing "the ball is in my room *or* your room" to "the ball is in my room *and* your room" produces a contradiction because a ball cannot be in two rooms at the same time.

It is important to discuss two issues regarding conceptual consistency. First, our diagnostic for consistency was quite strict. In many cases, propositions are not inconsistent in this sense but they are implausible. For example, drinking both tea and coffee at the same time is not inconsistent, but is unlikely. It is possible that many exclusive interpretations are based on such judgments of implausability. Second, if the coordinands are inconsistent, this does not necessarily mean that the connective interpretation must be exclusive. For example, in a sentence like "you could stay here or go out", the alternatives "staying here" and "going

out" are inconsistent. Yet, the overall interpretation of the connective could be conjunctive: you could stay here AND you could go out. The statement communicates that both possibilities hold. This pattern of interaction between possibility modals like *can* and disjunction words like *or* are often discussed under "free-choice inferences" in the semantics and pragmatics literature (Kamp, 1973; Von Wright, 1968). Another example is unconditionals such as "Ready or not, here I come!". The coordinands are contradictions: one is the negation of the other. However, the overall interpretation of the sentences is that in both cases, the speaker is going to come.

3. *Utterance Type*

Annotators decided whether an utterance was an instance of a declarative, an interrogative, or an imperative. Occasionally, we found examples with different utterance types for each coordinand. For example, a mother could say "put your backpack on and I'll be right back", where the first cooridnand is an imperative and the second a declarative. Such examples were coded for both utterance types with a dash inbetween: imperative-declarative. Table 6 in the appendix provides the detailed definitions and examples for each utterance type.

4. *Intonation Type*

Annotators listened to the utterances and decided whether the intonation contour on the coordination was flat, rise, or rise-fall. Table 5 in the appendix shows the definitions and examples for these intonation types. In order to judge the intonation of the sentence accurately, annotators were asked to construct all three intonation contours for the same sentence and see which one is closer to the actual intonation of the utterance. For example, to judge the sentence "do you want orange juice↑ or apple juice↓?", they reconstructed the sentence with the prototypical flat, rising, and rise-fall intonations and checked to see which intonation is closer to the actual one.

5. *Syntactic Level*

Annotators marked whether the coordination was at the clausal level or at the sub-clausal level. Clausal level was defined as sentences, clauses, verb phrases, and verbs. Coordination of other categories was coded as sub-clausal. This annotation category was introduced to check the hypothesis that the syntactic category of the coordinands may influence the interpretation of a coordination. For example, a sentence like "He drank tea or coffee" is less likely to be interpreted as exclusive than "He drank tea or he drank coffee." The clausal vs. sub-clausal distinction was inspired by the fact that in many languages, coordinators that connect sentences and verb phrases are different lexical items than those that connect nominal, adjectival, or prepositional phrases (see Haspelmath, 2007).

6. *Communicative Functions*

We constructed a set of categories that captured particular usages or communicative functions of the words *or* and *and*. They include descriptions, directives, preferences, identifications, definitions-examples, clarifications, repairs, and a few others shown in Table 9 in appendix. These communicative functions were created using the first 100 examples and then they were used for the classification of the rest of the examples. Some communicative functions are general and some are specific to coordination. For example, directives are a general class while conditionals (e.g. Put that out of your mouth, or I'm gonna put it away) are more specific to coordinated constructions. It is also important to note that the list is not unstructured. Some communicative functions are subtypes of others. For example, "identifications" and "unconditionals" are subtypes of "descriptions" while "conditionals" are a subtype of directives. Furthermore, "repairs" seem parallel to other categories in that any type of speech can be repaired. We do not fully explore the details of these functions in this study but such details matter for a general theory of acquisition that makes use of the speaker's communicative intentions as early coarse-grained communicative cues for the acquisition of fine-grained meaning such as function words.

7. *Answer Type*

Whenever a parent's utterance was a polar question, the annotators coded the utterance for the type of response it received from the children. This annotation category was different from others because it was not used as a cue for learning disjunction. Instead, it was used as an opportunity to assess, albeit in a limited and indirect way, the comprehension of children in the same corpus. Table 10 in the appendix shows the answer types in this study and their definitions and examples. Utterances that were not polar questions were simply coded as NA for this category. If children responded to polar questions with "yes" or "no", the category was YN and if they repeated with one of the coordinands the category was AB. If children said yes/no and followed it with one of the coordinands, the answer type was determined as YN (yes/no). For example, if a child was asked "Do you want orange juice or apple juice?" and the child responded with "yes, apple juice", our annotators coded the response as YN. The reason is that in almost all cases, if a simple yes/no response is felicitous, then it can also be optionally followed with mentioning a disjunct. However, if yes/no is not a felicitous response, then mentioning one of the alternatives is the only appropriate answer. For example, if someone asks "Do you want to stay here or go out?" a response such as "yes, go out" is infelicitous and a better response is simply "go out". Therefore, we counted responses with both yes/no and mentioning an alternative as a yes/no response.

8. *Negation and Modals*

Finally, a script was used to automatically mark utterances for whether they contain sentential negation (*not*/*n't*) or any modal auxiliary such as *maybe*, *can*, *could*, *should*, *would*, or *need to*. This allowed us to see how the presence or absence of negation or modals could affect the overall interpretation of the utterance.

Inter-annotator Reliability. To train annotators and confirm their reliability for disjunction examples, two annotators coded the same 240 instances of disjunction. The inter-annotator reliability was calculated over 8 iterations of 30 examples each. After each iteration, annotators met to discuss disagreements and resolve them. They also decided whether the category definitions or annotation criteria needed to be made more precise. Training was completed after three consecutive iterations showed substantial agreement between the annotators for all categories (Cohen's $\kappa > 0.7$). Further details on inter-annotator reliability are presented in the appendix section.

Results

We start with the category "answer type". This category can help us understand if children in the providence corpus provided appropriate answers to questions with disjunction. Figure 7 (Left) shows the monthly proportions of "yes/no" (Y/N) and alternative (AB) answers between the ages of 1 and 3 years. Initially, children provided no answer to questions, but by the age of 3 years, the majority of such questions received a yes/no (YN) or alternative (AB) answer. To assess how often these answers were appropriate, we defined appropriate answers the following way: an alternative (AB) answer is appropriate for an alternative question (one with "or" and a rise-fall intonation). A yes/no answer (YN) is appropriate for a yes/no (polar) question (one with *or* and a rising intonation). Of course this classification is strict and misses some nuanced cases, but nevertheless provides a useful conservative estimate. The right side of Figure 7 shows the monthly proportion of children's appropriate answers between the ages of 1 and 3. The results show that even with a conservative measure, children show an increase in the proportion of their appropriate answers to questions containing *or* between 20 to 30 months of age (roughly 2 and 3 years of age). This in turn suggests that initial form-meaning mappings for disjunction is formed in this age range. The rest of this section discusses the cues that can assist children create

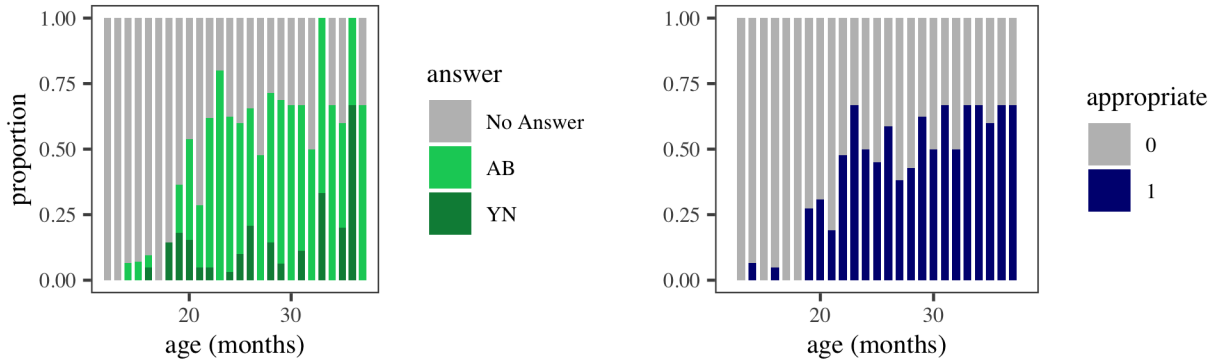


Figure 7. Left: Monthly proportions of children's yes/no (YN) and alternative (AB) answers to questions with *or*. Right: Monthly proportions of children's appropriate answers to questions with *or*.

successful form-meaning mappings.

First, we look at our dependent variable, namely "connective interpretations". Figure 8 (Left) shows the overall distribution of the connective interpretations in child-directed speech regardless of the connective word. The most common interpretation was conjunction (AND, 55%) followed by exclusive disjunction (XOR, 31%). Figure 8 (Right) shows the distribution of connective interpretations broken down by the connective word used: *and* vs. *or*[1]. Almost all instances of the connective *and*, were interpreted as conjunction (AND). There were also a small number of NAND interpretations (e.g. "don't swing that in the house and hit things with it") and IFF interpretations (e.g. "come here and I'll show you") in our sample. For the connective *or*, the most frequent interpretation was exclusive disjunction (XOR, 62%) followed by inclusive disjunction (IOR, 18%) and conjunction (AND, 11%). There were also a small number of NOR (e.g. "you never say goodbye or thank you") and NAB interpretations (e.g. "those screws, or rather, those nuts"). Overall, these results are consistent with the findings of Morris (2008) who concluded that exclusive disjunction is the most common interpretation of *or*. Therefore, by simply associating the most common

[1]All the confidence intervals shown in the plots for this section are simultaneous multinomial confidence intervals computed using the Sison and Glaz (1995) method.

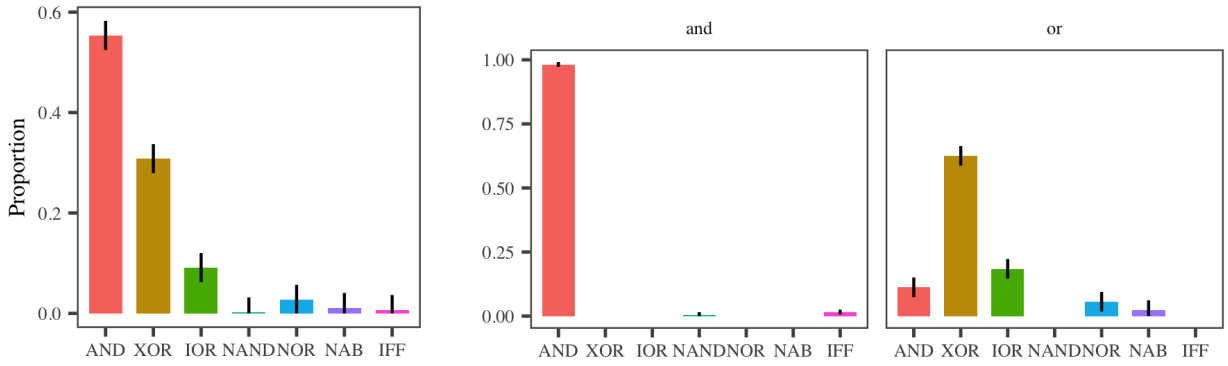


Figure 8. Left: Connective interpretations in child-directed speech. Right: Connective interpretations broken down by lexical items *and* (conjunction) and *or* (disjunction).

interpretations with the connective words, a learner is expected to learn *and* as conjunction, and *or* as exclusive disjunction (Crain, 2012; Morris, 2008).

However, the learning outcome might be different if factors other than the connective word are also considered. In what follows, we investigate how different annotation categories introduced earlier correlate with the interpretations of *or*. We set *and* aside because it was almost always interpreted as conjunction (AND). Figure 9 shows the proportions of connective interpretations in disjunctions with consistent vs. inconsistent disjuncts. When the disjuncts were consistent (i.e. could be true at the same time), the interpretation could be exclusive (XOR), inclusive (IOR), or conjunctive (AND). When the disjuncts were inconsistent, a disjunction almost always received an exclusive (XOR) interpretation. This suggests that the exclusive interpretation of a disjunction often stems from the inconsistent or contradictory nature of the disjuncts themselves[2].

[2]It should be noted here that in all *and*-examples, the disjuncts were consistent. This is not surprising given that inconsistent meanings with *and* result in a contradiction. The only exception to this was one example where the mother was mentioning two words as antonyms: "short and tall". This example is quite different from the normal utterances given that it is meta-linguistic and list words rather than asserting the content of the words.

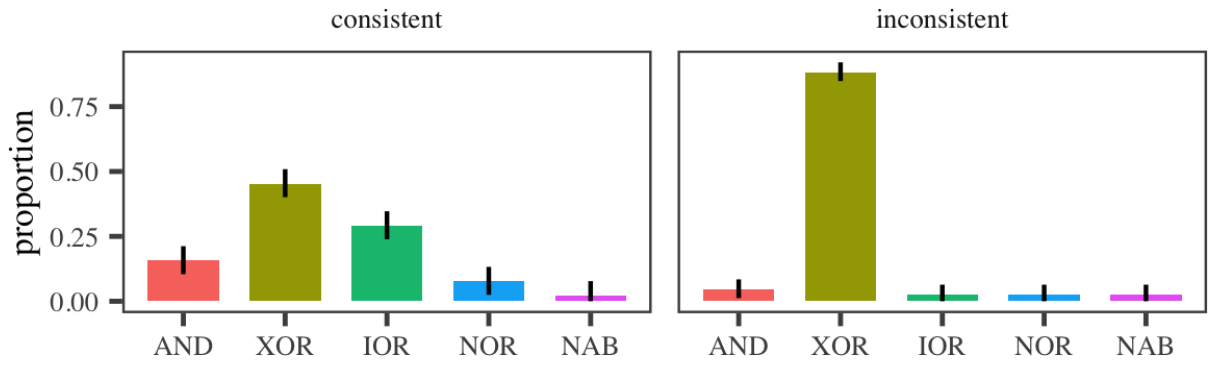


Figure 9. Interpretations of disjunction with consistent vs. inconsistent disjuncts.

Next we focus on cases of disjunction with consistent disjuncts. Figure 10 shows their interpretations in declarative, interrogative, and imperative sentences. Interrogatives selected for exclusive and inclusive interpretations. Imperatives were more likely to be interpreted as inclusive (IOR), but declaratives could receive almost any interpretation: conjunctive (AND), exclusive (XOR), inclusive (IOR), or even that "neither" disjunct was true (NOR). A common example of inclusive imperatives was invitation to action such as "Have some food or drink!". Such invitational imperatives seem to convey inclusivity (IOR) systematically. They are often used to give the addressee full permission with respect to both alternatives. It can in fact be odd to use them to imply exclusivity (e.g. "Have some food or drink, but not both!"), and they are not conjunctive either, i.e inviting the addressee to do both actions (e.g. "Have some food, and have some drink!").

While interrogatives selected for exclusive and inclusive interpretations, their intonation could distinguish between these two readings. Figure 11 shows the interpretations of consistent disjunction in three intonational contours: flat, rise, and rise-fall. The rise and rise-fall contours are typical of interrogatives. The results show that, a disjunction with a rise-fall intonation is most likely interpreted as exclusive (XOR). If the intonation is rising, a disjunction is most likely inclusive (IOR). Finally, a disjunction with a flat intonation

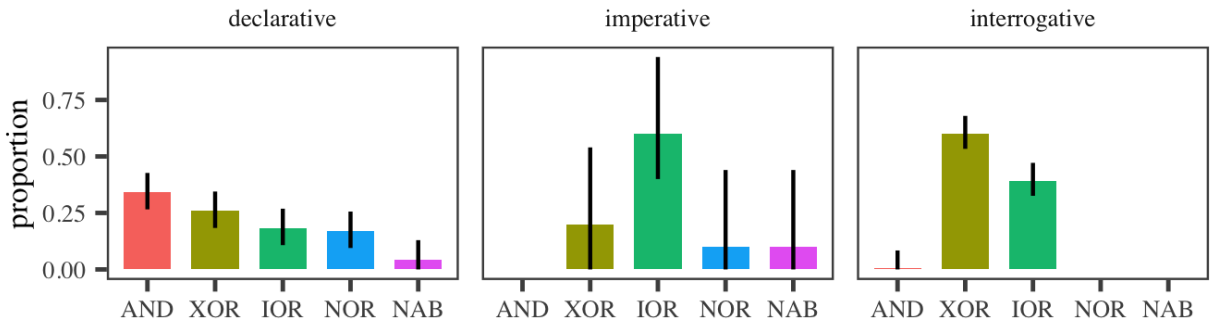


Figure 10. Interpretations of disjunction with consistent disjuncts in interrogative, imperative, and declarative utterances.

(typical of declaratives and imperatives) could be interpreted as exclusive (XOR), conjunctive (AND), inclusive (IOR), or neither (NOR). These results replicate Pruitt and Roelofsen (2013)'s experimental findings on the role of intonation in the interpretation of polar and alternative questions.

Next we focus on consistent disjunctions with flat intonation. Figure 12 breaks down the interpretations based on whether the utterance contained negation or modals. The results show that in the presence of a modal such as *can* or *maybe*, it was more likely for a disjunction to have a conjunctive interpretation. This is consistent with the literature on free-choice inferences in formal semantics and pragmatics (Kamp, 1973), which shows statements such as "you can have tea or coffee" is interpreted conjunctively as "you can have tea *and* you can have coffee". When the utterance contained a negation, the disjunction could be interpreted as exclusive (XOR) or neither (NOR). These two interpretations correspond to the scope relations between negation and disjunction. If negation scopes above disjunction, we get a neither (NOR) interpretation (e.g. "I do not eat cauliflower, cabbage or baked beans.") But if disjunction scopes above negation, the likely interpretation is exclusive (e.g. don't throw it at the camera or you're going in the house.) These results also suggest that a learner who tracks co-occurences of *or* with negative morphemes can potentially learn

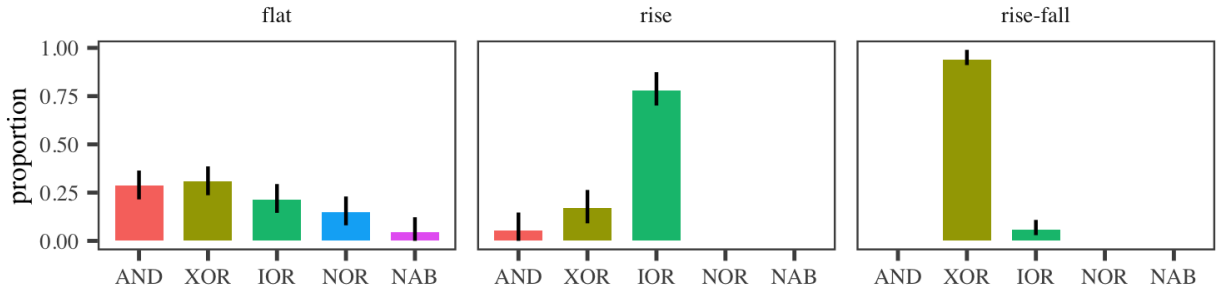


Figure 11. Interpretations of disjunction with consistent disjuncts and flat, rising, or rise-fall intonation.

about the scope interaction of disjunction and negative particles in their native language.

Finally, we visit the last two remaining categories: syntactic level and communicative functions. For these categories, we show connective interpretations over all instances of disjunction. Figure 13 shows connective interpretations, broken down by syntactic level. The results suggest a possible small effect of clausal level disjuncts. Disjunctions were more likely to be interpreted as exclusive if their disjuncts were clauses or verbs rather than nominals, adjectives, or prepositions (all sub-clausal units). As explained before, the intuition is that a sentences such as "They had tea or coffee" is less likely to be exclusive than "they had tea or they had coffee" However, our understanding is that compared to other factors such as intonation and consistency, the effect of syntactic level was very small. As we shall see in Study 3, a computational learning model did not find syntactic level to be of much use for classifying instances of disjunction as exclusive, above and beyond what other annotation categories offered.

Figure 14 shows connective interpretations in the 10 different communicative functions we defined. The results show that certain functions increase the likelihood of some connective interpretations. An exclusive interpretation (XOR) is common in acts of clarification, identification, stating/asking preferences, stating/asking about a description, or making a

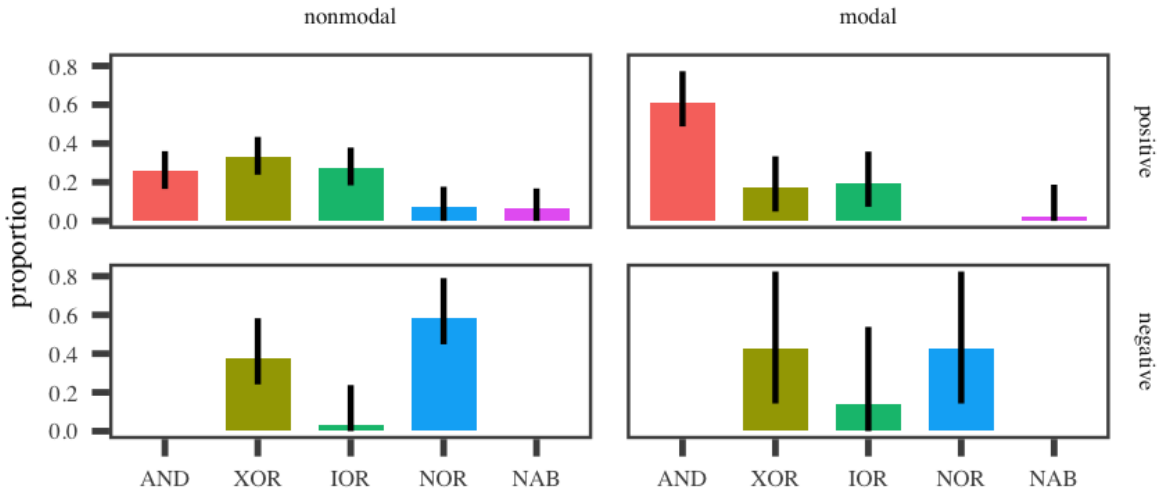


Figure 12. Distribution of connective interpretations for consistent disjuncts with flat intonation.

conditional statements. These results are consistent with expectations on the communicative intentions that these utterances carry. In clarifications, the speaker needs to know which of two alternatives the other party meant. Similarly in identifications, speaker needs to know which category does a referent belongs to. In preferences, parents seek to know which of two alternatives the child wants. Even though descriptions could be either inclusive or exclusive, in the current sample, most descriptions were questions about the state of affairs and required the child to provide one of the alternatives as the answer. In conditionals such as "come here or you are grounded", the point of the threat is that only one disjunct can be true: either "you come and you are not grounded" or "you don't come and you are grounded".

Repairs often received an exclusive (XOR) or a second-disjunct-true (NAB) interpretation. This is expected given that in repairs the speaker intends to say that the first disjunct is incorrect or inaccurate. Unconditionals and definitions/examples always had a conjunctive (AND) interpretation. Again, this is to be expected. In such cases the speaker intends to communicate that all options apply. If the mother says that "cats are animals like

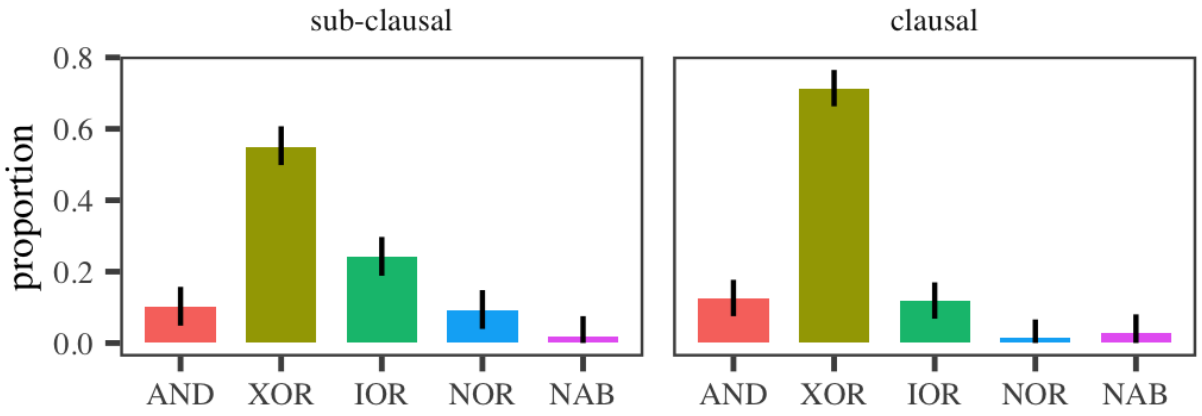


Figure 13. Top: Interpretations of clausal vs. sub-clausal disjunction. Down: Interpretations of clausal vs. sub-clausal disjunction in declaratives with consistent disjuncts.

lions or tigers", she intends to say that both lions and tigers are cats, and not one or the other. Interestingly, in some cases, *or* is replaceable by *and*: "cats are animals like lions and tigers". In unconditionals, the speaker communicates that in both alternatives, a certain proposition holds. For example, if the mother says "ready or not, here I come!", she communicates that "I come" is true in both cases where "you are ready" and "you are not ready".

Options were often interpreted either as conjunctive (AND) or inclusive (IOR). The category "options" contained examples of free-choice inferences such as "you could drink orange juice or apple juice". This study found free-choice examples to be more common in child-directed speech than the current literature on the acquisition of disjunction assumes. Finally, directives received either an IOR or XOR interpretation. It is important to note here that the most common communicative function in the data were preferences and descriptions. Other communicative functions such as unconditionals or options were fairly rare. Despite their infrequent appearance, these constructions must be learned by children at some point, since almost all adults know how to interpret them.

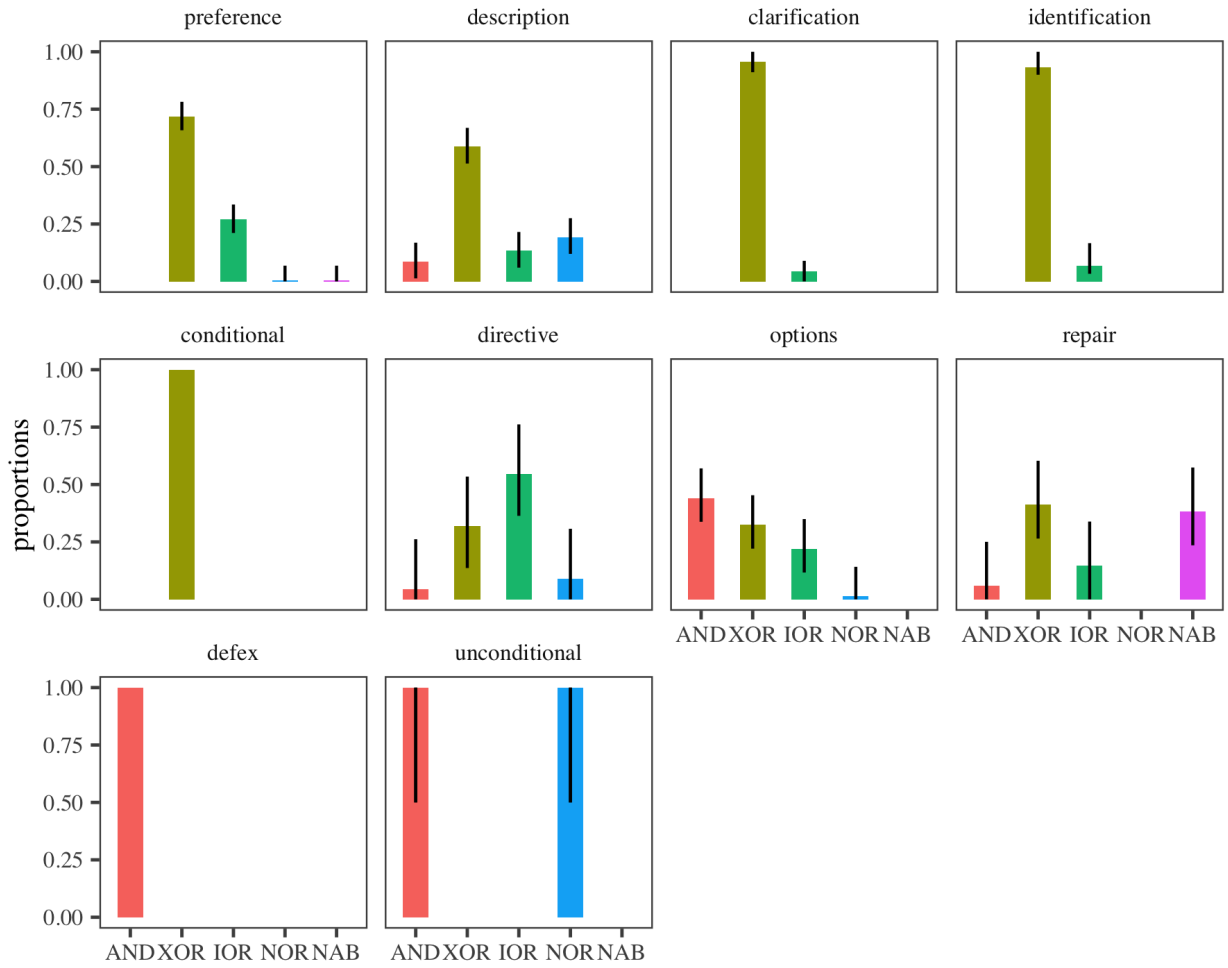


Figure 14. Interpretations of disjunction in different communicative functions.

Conclusion

This study focused on the interpretations that connectives *and* and *or* recieve in child-directed speech. It also investigated some candidate cues that can help children's learning of these interpretations. The study selected 1000 examples of *and* and *or* in child-directed speech, annotated for their truth-conditional interpretation, as well as six candidate cues: (1) Conceptual Consistency (2) Utterance Type; (3) Intonation; (4) Presence of negative or modal morphemes (5) Syntactic Level; and (6) Communicative Function. Like Morris (2008), this study found that the most common interpretations of *and* and *or* are

conjunction (AND) and exclusive disjunction (XOR) respectively. Therefore, relying only on connective word forms, a learner should expect *and* to be a conjunction and *or* exclusive disjunction.

However, the study also found that the most likely interpretation of a disjunction depended on the cues that accompanied it in context. A disjunction was most likely exclusive if the alternatives were inconsistent (i.e. contradictory). A disjunction with consistent alternatives was either inclusive or exclusive if it appeared in a question. Within questions, a disjunction was most likely exclusive if its intonation was "rise-fall", and inclusive if it was "rising". Among declaratives and imperatives with "flat" intonations, a disjunction was interpreated most liklely as AND if there was a modal, and NOR or XOR if there was negation present in the utterance. Finallly, in the absence of all these cues, a disjunction was more likely to be non-exclusive (IOR + AND) than exclusive (XOR). These results suggest that a learner can potentially use these cues to predict the intended interpretation of a connective in utterance context. In the next study, we use a computational learning model to formalize this account.

Study 3: Computational Modeling Using Decision Trees

A decision tree is a classification model structured as a hierarchical tree with nodes, branches, and leaves (Breiman, 2017). The tree starts with an initial node, called the root, and branches into more nodes until it reaches the leaves. Each node represents the test on a feature, each branch represents an outcome of the test, and each leaf represents a classification label. Using a decision tree, observations can be classified or labeled based on a set of features.

Decision trees have several advantages for modeling cue-based accounts of semantic acquisition. First, decision trees use a set of features to predict the classification of

observations. This is analogous to using cues to predict the correct interpretation of a word or an utterance. Second, unlike many other machine learning techniques, decision trees result in models that are interpretable. Third, the order of decisions or features used for classification is determined based on information gain. Features that appear higher (earlier) in the tree are more informative and helpful for classification. Therefore, decision trees can help us understand which cues are probably more helpful for the acquisition and interpretation of a word.

Decision tree learning is the construction of a decision tree from labeled training data. This section applies decision tree learning to the annotated data of Study 3 by constructing random forests (Breiman, 2001; Ho, 1995). In random forest classification, multiple decision trees are constructed on subsets of the data, and each tree predicts a classification. The ultimate outcome is a majority vote of each trees classification. Since decision trees tend to overfit data, random forests control for overfitting by building more trees and averaging their results. **(Citation)** Next section discusses the methods used in constrcting the random forests for interpreting connectives *or*/*and*.

Methods

The random forest models were constructed using python's Sci-kit Learn package (Pedregosa et al., 2011). The annotated data had a feature array and a connective interpretation label for each connective use. Connective interpretations included exclusive (XOR), inclusive (IOR), conjunctive (AND), negative inclusive (NOR), and NPQ which states that only the second proposition is true. The features or cues used included all other annotation categories: intonation, consistency, syntactic level, utterance type, and communicative function. All models were trained with stratified 10-Fold cross-validation to reduce overfitting. Stratified cross-validation maintains the distribution of the initial data in the random sampling to build cross validated models. Maintaining the data distribution

ensures a more realistic learning environment for the forests. Tree success was measured with F1-Score, harmonic average of precision and recall **(Citation)**.

First a grid search was run on the hyperparamter space to establish the number of trees in each forest and the maximum tree depth allowable. The grid search creates a grid of all combinations of forest size and tree depth and then trains each forest from this grid on the data. The forests with the best F1-score and lowest size/depth are reported. **(Citation*) **The default number of trees for the forests was set to 20, with a max depth of eight and a minimum impurity decrease of 0. Impurity was measured with gini impurity, which states the odds that a random member of the subset would be mislabled if it were randomly labeled according to the distribution of labels in the subset.** (Citation)**

Decision trees were fit with high and low minimum gini decrease values. High minimum gini decrease results in a tree that does not use any features for branching. Such a tree represents the baseline or traditional approach to mapping that directly maps a word to its most likely interpretation. Low minimum gini decrease allows for a less conservative tree that uses multiple cues/features to predict the interpretation of a disjunction. Such a tree represents the cue-based context-sensitive account of word learning discussed in the previous section.

Results

We first present the results of the random forests in the binary classification task. The models were trained to classify exclusive and inclusive interpretations of disjunction. For visualization of trees, we selected the highest performing tree in the forest by testing each tree and selecting for highest F1 score. While the forests performance is not identical to the highest performing tree, the best tree gives an illustrative example of how the tree performs.

Figure 15 shows the best performing decision tree with high minimum gini decrease. As expected, a learner that does not use any cues would interpret *or* as exclusive all the time. This is the baseline model. Figure 16 shows the best performing decision tree with low minimum gini decrease. The tree has learned to use intonation and consistency to classify disjunctions as exclusive or inclusive. As expected, if the intonation is rise-fall or the disjuncts are inconsistent, the interpretation is exclusive. Otherwise, the disjunction is classified as inclusive.

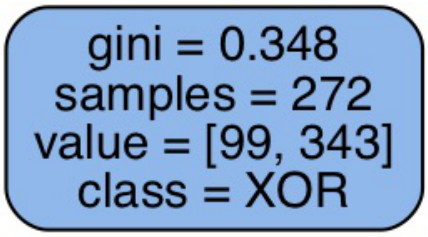


Figure 15. Baseline tree grown with minimum impurity decrease of 0.2. The tree always classifies examples of disjunction as exclusive.

Figure 17 shows the average F1 scores of the baseline and cue-based models in classifying exclusive examples. The models perform relatively well and similar to each other, but the cue-based model performs slightly better. The real difference between the baseline model and the cue-based model is in their performance on inclusive examples. Figure 18 shows the F1 score of the forests as a function of the training size in classifying inclusive examples. As expected, the baseline model performs very poorly while the cue-based model does a relatively good job and improves with more examples.

Next, we use decision tree learning in a ternary classification task. The model uses

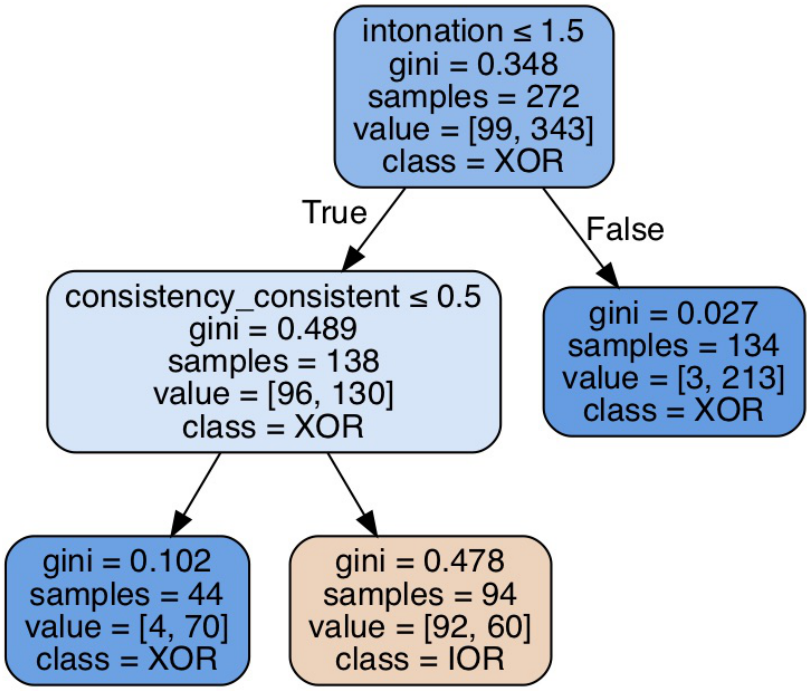


Figure 16. Cue-based tree grown with minimum impurity decrease of 0.01. The tree classifies examples of disjunction with rise-fall intonation as exclusive (intonation > 1.5). If the intonation is not rise-fall but the disjuncts are inconsistent (consistency < 0.5), then the disjunction is still classified as exclusive. However, if neither of these two hold, the disjunction is classified as inclusive.

features to interpret a coordination with *and* and *or* as inclusive (IOR), exclusive (XOR), or conjunctive (AND). Figure 19 shows the baseline decision tree with high minimum gini decrease, which only uses the presence of the words *or*/*and* to interpret conjunction and disjunction. As expected, the tree interprets a coordination with *and* as a conjunction and one with *or* as exclusive disjunction. Figure 20 shows the cue-based decision tree with low minimum gini decrease. In addition to the presence of *and* and *or*, the tree uses intonation, consistency, communicative function, and utterance type to distinguish exclusive, inclusive,

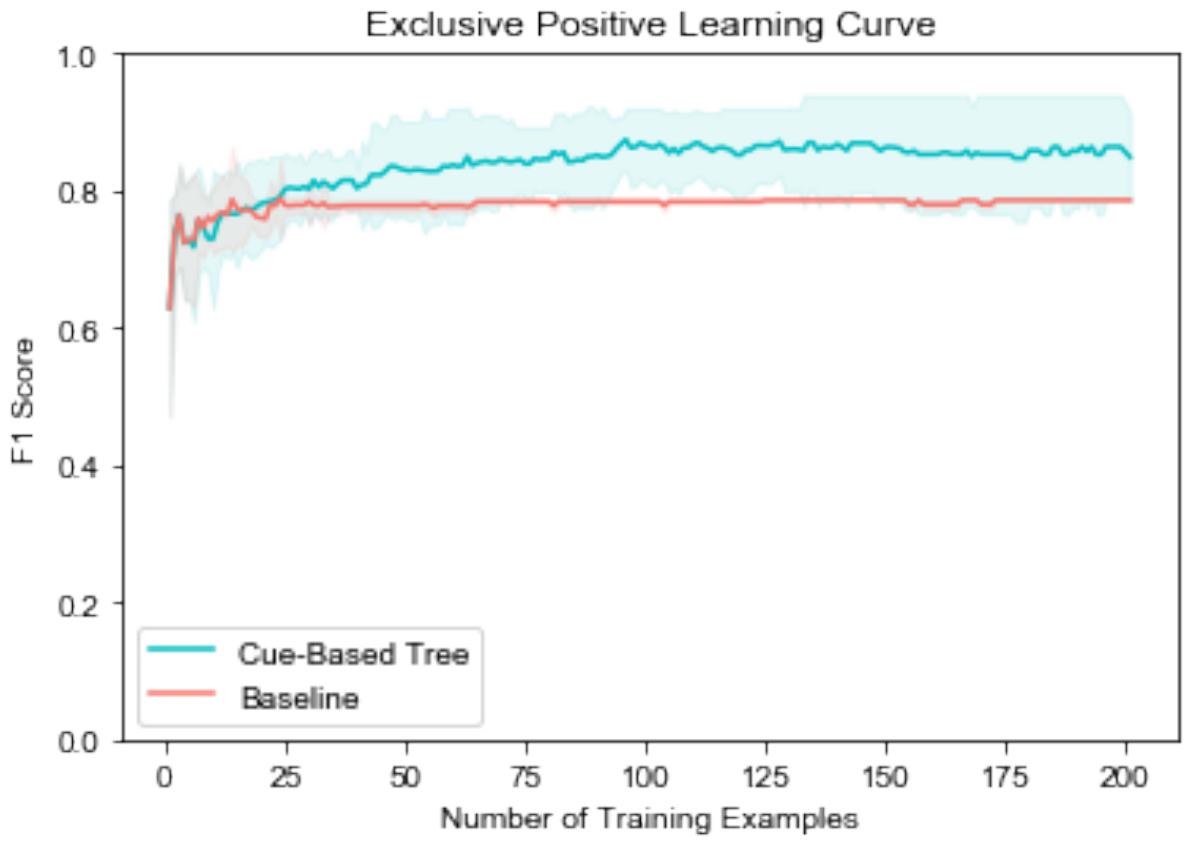


Figure 17. The average F1 score for class XOR (exclusive) as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

and conjunctive uses of disjunction. In short, a disjunction that is rise-fall, inconsistent, or has a conditional communicative function is classified as exclusive. Otherwise the disjunction is classified as inclusive. The tree also finds conjunctive interpretations of disjunction more likely in declarative sentences than interrogatives.

Figure 21 shows the average F1 score of the conjunctive interpretations (AND) for the baseline and the cue-based models. Since the vast majority of the conjunctive interpretations are predicted by the presence of the word *and*, the baseline and cue-based models show similar performances. Setting aside conjunction examples, Figure 22 shows the average F1 score of the AND interpretation of disjunction only. Here we see that the cue-based model

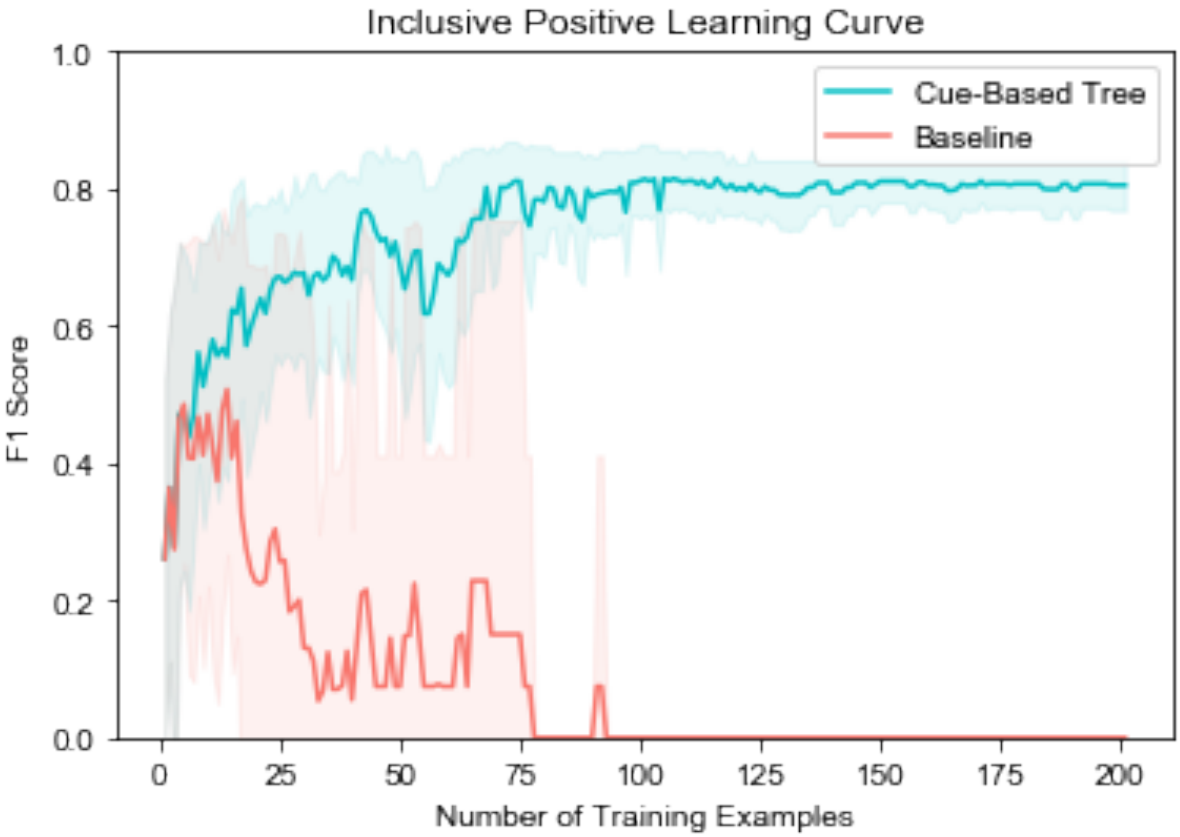


Figure 18. The average F1 score for class IOR (inclusive) as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

performs better than the default model in guessing conjunctive interpretations of disjunction. The informal analysis of the trees suggest that the model does this by using the "speech act" cue. Figure 23 shows the average F1-score of the exclusive interpretations (XOR) for the baseline and the cue-based models. The cue-based model does slightly better than the baseline model. As before, the most important improvement comes in identifying inclusive examples. Figure 24 shows the average F1-score of the inclusive interpretations (IOR) for both baseline and cue-based models. The baseline model performs very poorly while the cue-based model is capable of classifying inclusive examples as well.

Finally, welook at decision trees trained on the annotation data to predict all the

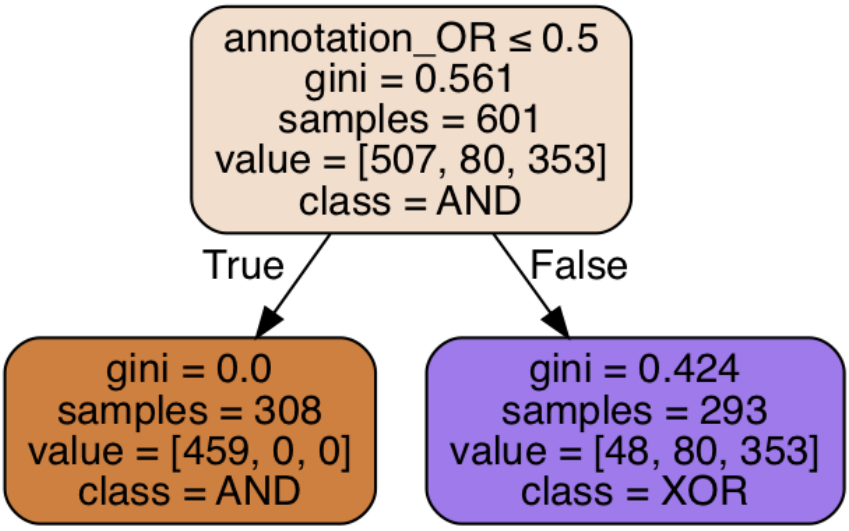


Figure 19. The baseline tree grown on conjunctions and disjunctions with minimum impurity decrease of 0.2. The tree uses the words *and/or* and classifies them as conjunction and exclusive disjunction respectively.

interpretation classes for disjunction: AND, XOR, IOR, NOR, and NPQ. Figure 25 shows the baseline model that only uses the words *and* and *or* to classify. As expected, *and* receives a conjunctive interpretation (AND) and *or* receives an exclusive interpretation (XOR). Figure 26 shows the best example tree of the cue-based model. The leaves of the tree show that it recognizes exclusive, inclusive, conjunctive, and even negative inclusive (NOR) interpretations of disjunction. How does the tree achieve that? Like the baseline model, the tree first asks about the connective used: *and* vs. *or*. Then like the previous models, it asks about intonation and consistency. If the intonation is rise-fall, or the disjuncts are inconsistent, the interpretation is exclusive. Then it asks whether the sentence is an interrogative or a declarative. If interrogative, it guesses an inclusive interpretation. This basically covers questions with a rising intonation. Then the tree picks declarative examples

that have conditional speech act (e.g. “give me the toy or you’re grounded”) and labels them as exclusive. Finally, if negation is present in the sentence, the tree labels the disjunction as NOR.

Figures 27, 28, and 29 show the average F1-scores for the conjunctive (AND), exclusive (XOR), and inclusive (IOR) interpretations as a function of training size. The results are similar to what wereported before with the ternary classification. While the cue-based model generally performs better than the baseline model, it shows substantial improvement in classifying inclusive cases.

Figure 30 shows the average F1-score for the negative inclusive interpretation as a function of training size. Compared to the baseline model, the cue-based model shows a substantially better performance in classifying negative sentences. The success of the model in classifying negative inclusive examples (NOR) suggests that the cue-based model offers a promising approach for capturing the scope relation of operators such as negation and disjunction. Here, the model learns that when negation and disjunction are present, the sentence receives a negative inclusive (NOR) interpretation. In other words, the model has learned the narrow-scope interpretation of negation and disjunction from the input data. In a language where negation and disjunction receive an XOR interpretation (not A or not B), the cue-based model can learn the wide-scope interpretation of disjunction.

Finally, Figure 31 shows the average F1 score for the class NPQ. This interpretation suggested that the first disjunct is false but the second true. It was seen in examples of repair most often and the most likely cue to it was also the communicative function or speech act of repair. The results show that even though there were improvements in the cue-based model, they were not stable as shown by the large confidence intervals. It is possible that with larger training samples, the cue-based model can reliably classify the NPQ interpretations as well.

Discussion

We considered two accounts for the acquisition of function words. The first account was a baseline (context-independent) account that is used in vanilla cross-situational word learning: words are isolated and directly mapped to their most frequent meanings. The second account is what I called the cue-based context-dependent mapping in which words are mapped to meanings conditional on a set of present cues in the context. I argued that the puzzle of learning disjunction arises because in the baseline account, forms are mapped directly to meanings without considering the context of use. Under this account, the input statistics supports an exclusive interpretation for *or*. However, comprehension studies show that children can interpret *or* as inclusive. I showed that the cue-based account resolves this problem by allowing *or* to be mapped to its interpretation according to the set of contextual cues that disambiguate it. The results of computational experiments with decision tree learning on data from child-directed speech suggested that such an approach can successfully learn to classify a disjunction is inclusive or exclusive. More broadly, cue-based context-dependent mapping is useful for the acquisition of ambiguous words and interpretations that are consistent but relatively infrequent in child-directed speech.

Conclusion

The case of disjunction shows that word learning requires to systmatically take different aspects of the linguistic and non-linguistic context into account. The meaning of a word such as *or* cannot be learned independent of its context such as its intonation contour, the meaning of the coordinands it conjoins, or type of speech act it participates in.

Table 2

Number of and's, or's, and the total number of words in the speech of children and their parents in English-North America and English-UK collections after exclusions.

Speaker Role	and	or	total
Father	15,488	1,683	967,075
Mother	153,781	14,288	8,511,478
Target_Child	78,443	2,590	4,681,056

References

Appendix

Properties of CHILDES Corpora

In this section, I report some results on the distribution of words and utterances among the speakers in our collection of corpora. The collection contained 14,159,609 words. Table (2) shows the total number of *and*'s, *or*'s, and words in the speech of children, fathers, and mothers. The collection contains 9 times more words for mothers compared to fathers and 2 more words for mothers compared to children. Therefore, the collection is more representative of the mother-child interactions than father-child interactions. Compared to *or*, the word *and* is 10.80 times more likely in the speech of mothers, 9.20 times more likely in the speech of fathers, and 30.30 times more likely in the speech of children. Overall, *and* is 13.35 times more likely than *or* in this collection which is close to the rate reported by Morris (2008) who used a smaller subset of CHILDES. He extracted 5,994 instances of *and* and 465 instances of *or* and found that overall, *and* was 12.89 times more frequent than *or* in parent-child interactions.

Figure **??** shows the number of words spoken by parents and children at each month of

the child's development. The words in the collection are not distributed uniformly and there is a high concentration of data between the ages of 20 and 40 months (around 2 to 3 years of age). There is also a high concentration around 60 months (5 years of age). The speech of fathers shows a relatively low word-count across all ages. Therefore, in our analyses we should be more cautious in drawing conclusions about the speech of fathers generally, and the speech of mothers and children after age 5. The distribution of function words is sensitive to the type of utterance or more broadly the type of speech act produced by speakers. Therefore, it is important to check the distribution of speech acts in corpora when studying different function words. Since it is hard to classify and quantify speech acts automatically, here I use utterance type as a proxy for speech acts. I investigate the distribution of declaratives, questions, and imperatives in this collection of corpora on parent-child interactions. Figure 33 shows the distribution of different utterance types in the speech of parents and children. Overall, most utterances are either declaratives or questions, and there are more declaratives than questions in this collection. While mothers and fathers show similar proportions of declaratives and questions in their speech, children produce a lower proportion of questions and higher proportion of declaratives than their parents.

Figure 34 shows the developmental trend of declaratives and questions between the ages of one and six. Children start with only producing declaratives and add non-declarative utterances to their repertoire gradually until they get closer to the parents' rate around the age six. They also start with very few questions and increase the number of questions they ask gradually. It is important to note that the rates of declaratives and questions in children's speech do not reach the adult rate. These two figures show that parent-child interactions are asymmetric. Parents ask more questions and children produce more declaratives. This asymmetry also interacts with age: the speech of younger children has a higher proportion of declaratives than older children.

The frequency of function words such as *and* and *or* may be affected by such

conversational asymmetries if they are more likely to appear in some utterance types than others. Figure 35 shows the proportion of *and*'s and *or*'s that appear in different utterance types in parents' and children's speech. In parents' speech, *and* appears more often in declaratives (around 60% in declaratives and 20% in questions). On the other hand, *or* appears more often in questions than declaratives, although this difference is small in mothers. In children's speech, both *and* and *or* appear most often in declaratives. However, children have a higher proportion of *or* in questions than *and* in questions.

The differences in the distribution of utterance types can affect our interpretation of the corpus data on function words such as *and* and *or* in three ways. First, since the collection contains more declaratives than questions, it may reflect the frequency and diversity of function words like *and* that appear in declaratives better. Second, since children produce more declaratives and fewer questions than parents, we may underestimate children's knowledge of function words like *or* that are frequent in questions. Third, given that the percentage of questions in the speech of children increases as they get older, function words like *or* that are more likely to appear in questions may appear infrequent in the early stages and more frequent in the later stages of children's development. In other words, function words like *or* that are common in questions may show a seeming delay in production which is possibly due to the development of questions in children's speech. Therefore, in studying children's productions of function words, it is important to look at their relative frequencies in different utterance types as well as the overall trends. This is the approach I pursue in the next section.

Table 3

Information on the participants in the Providence Corpus. Ethan was diagnosed with Asperger's syndrome and therefore was excluded from this study.

Name	Age Range	Sessions
Alex	1;04.28-3;05.16	51

Name	Age Range	Sessions
Ethan	0;11.04-2;11.01	50
Lily	1;01.02-4;00.02	80
Naima	0;11.27-3;10.10	88
Violet	1;02.00-3;11.24	51
William	1;04.12-3;04.18	44

Annotation Categories

Table 4

Annotation classes for connective interpretation

Class	Meaning	Examples
AND	Both propositions are true	*"I'm just gonna empty this and then I'll be out of the kitchen." – "I'll mix them together or I could mix it with carrot, too."*
IOR	One or both propositions are true	*"You should use a spoon or a fork." – "Ask a grownup for some juice or water or soy milk."*
XOR	Only one proposition is true	*"Is that a hyena? or a leopard?" – "We're gonna do things one way or the other."*
NOR	Neither proposition is true	*"I wouldn't say boo to one goose or three." – "She found she lacked talent for hiding in trees, for chirping like crickets, or humming like bees."*
IFF	Either both propositions are true or both are false	*"Put them [crayons] up here and you can get down. – Come over here and I'll show you."*

Class	Meaning	Examples
NAB	The first proposition is false, the second is true.	*"There's an Oatio here, or actually, there's a wheat here."*

Table 5

Definitions of the intonation types and their examples.

Intonation	Definitions	Examples
Flat	Intonation does not show any substantial rise at the end of the sentence.	*"I don't hear any meows or bow-wow-wows."*
Rise	There is a substantial intonation rise on each disjunct or generally on both.	*"Do you want some seaweed? or some wheat germ?"*
Rise-Fall	There is a substantial rise on the non-final disjunct(s), and a fall on the final disjunct.	*"Is that big Q or little q?"* – *"(are) You patting them, petting them, or slapping them?"*

Table 6

Definitions of the utterance types and their examples.

Utterance Types	Definitions	Examples
Declarative	A statement with a subject-verb-object word order and a flat intonation.	*"It looks a little bit like a drum stick or a mallet."*
Interrogative	A question with either subject-auxiliary inversion or a rising terminal intonation.	*"Is that a dog or a cat?"*

Utterance Types	Definitions	Examples
Imperative	A directive with an uninflected verb and no subject	*"Have a little more French toast or have some of your juice."*

Table 7

Definitions of the syntactic levels and their examples.

Syntactic Level	Definitions	Examples
Clausal	The coordinands are sentences, clauses, verb phrases, or verbs.	*"Does he lose his tail sometimes and Pooh helps him and puts it back on?"*
Sub-clausal	The coordinands are nouns, adjectives, noun phrases, determiner phrases, or prepositional phrases.	*"Hollies can be bushes or trees."*

Table 8

Definitions of consistency types and their examples.

Consistency	Definitions	Examples
Consistent	The coordinands can be true at the same time.	*"We could spell some things with a pen or draw some pictures."*
Inconsistent	The coordinands cannot be true at the same time.	*"Do you want to stay or go?"*

Table 9

Definitions of the communicative functions and their examples.

Function	Definitions	Examples
Descriptions	Describing what the world is like or asking about it. The primary goal is to inform the addressee about how things are.	"*It's not in the ditch or the drain pipe.*"
Identifications	Identifying the category membership or an attribute of an object. Speaker has uncertainty. A subtype of "Description".	"*Is that a ball or a balloon honey?*"
Definitions and Examples	Providing labels for a category or examples for it. Speaker is certain. Subtype of Description.	*"This is a cup or a mug."* – *"berries like blueberry or raspberry"*
Preferences	Asking what the addressee wants or would like or stating what the speaker wants or would like	*"Do you wanna play pizza or read the book?"*
Options	Either asking or listing what one can or is allowed to do. Giving permission, asking for permission, or describing the possibilities. Often the modal "can" is either present or can be inserted.	*"You could have wheat or rice."*

Function	Definitions	Examples
Directives	Directing the addressee to act or not act in a particular way. Common patterns include "let's do . . . ", "Why don't you do . . . ", or prohibitions such as "Don't . . . ". The difference with "options" is that the speaker expects the directive to be carried out by the addressee. There is no such expectation for "options".	*"let's go back and play with your ball or we'll read your book."*
Clarifications	Something is said or done as a communicative act but the speaker has uncertainty with respect to the form or the content.	*"You mean boba or bubble?"*
Repairs	Speaker correcting herself on something she said (self repair) or correcting the addressee (other repair). The second disjunct is what holds and is intended by the speaker. The speaker does not have uncertainty with respect to what actually holds.	*"There's an Oatio here, or actually, there's a wheat here."*
Conditionals	Explaining in the second coordinand, what would follow if the first coordinand is (or is not) followed. Subtype of Directive.	*"Put that out of your mouth, or I'm gonna put it away."* – *"Come over here and I'll show you."*

Function	Definitions	Examples
Unconditionals	Denying the dependence of something on a set of conditions. Typical format: "Whether X or Y, Z". Subtype of Descriptions.	*"Ready or not, here I come!"* (playing hide and seek)

Table 10

Definitions of answer types and their examples.

Type	Definitions	Examples
No Answer	The child provides no answer to the question.	Mother: *"Would you like to eat some applesauce or some carrots?"* Child: *"Guess what Max!"*
YN	The child responds with *yes* or *no*.	Father: *"Can I finish eating one or two more bites of my cereal?"* Child: *"No."*
AB	The child responds with one of the disjuncts (alternatives).	Mother: *"Is she a baby elephant or is she a toddler elephant?"* Child: *"It's a baby. She has a tail."*

Inter-annotator agreement

Figure 36 shows the percentage agreement and the kappa values for each annotation category over the 8 iterations.

Agreement in the following three categories showed substantial improvement after better and more precise definitions and annotation criteria were developed: connective interpretation, intonation, and communicative function. First, connective interpretation showed major improvements after annotators developed more precise criteria for selecting the propositions under discussion and separately wrote down the two propositions connected by the connective word. For example, if the original utterance was "do you want milk or juice?", the annotators wrote "you want milk, you want juice" as the two propositions under discussion. This exercise clarified the exact propositions under discussion and sharpened annotator intuitions with respect to the connective interpretation that is communicated by the utterance. Second, annotators improved agreement on intonation by reconstructing an utterance's intonation for all three intonation categories. For example, the annotator would examine the same sentence "do you want coffee or tea?" with a rise-fall, a rise, and a flat intonation. Then the annotator would listen to the actual utterance and see which one most resembled the actual utterance. This method helped annotators judge the intonation of an utterance more accurately. Finally, agreement on communicative functions improved as the definitions were made more precise. For example, the definition of "directives" in Table 9 explicitly mentions the difference between "directives" and "options". Clarifying the definitions of communicative functions helped improve annotator agreement.

Inter-annotator reliability for conjunction was calculated in the same way. Two different annotators coded 300 utterances of *and*. Inter-annotator reliability was calculated over 10 iterations of 30 examples. Figure 37 shows the percentage agreement between the annotators as well as the kappa values for each iteration. Despite high percentage agreement between annotators, the kappa values did not pass the set threshold of 0.7 in three consecutive iterations. This paradoxical result is mainly due to a property of kappa. An imbalance in the prevalence of annotation categories can drastically lower its value. When one category is extremely common with high agreement while other categories are rare, kappa will be low (Cicchetti & Feinstein, 1990; Feinstein & Cicchetti, 1990). In almost all annotated categories

for conjunction, there was one class that was extremely prevalent. In such cases, it is more informative to look at the class specific agreement for the prevalent category than the overall agreement measured by Kappa (Cicchetti & Feinstein, 1990; Feinstein & Cicchetti, 1990).

Table 11 lists the dominant classes as well as their prevalence, the values of class specific agreement index, and category agreement index (Kappa). Class specific agreement index is defined as $2n_{ii}/n_{i.} + n_{.i}$, where i represents the class's row/column number in the category's confusion matrix, n the number of annotations in a cell, and the dot ranges over all the row/column numbers (Fleiss, Levin, & Paik, 2013, p. 600; Ubersax, 2009). The class specific agreement indices are high for all the most prevalent classes showing that the annotators had very high agreement on these class, even though the general agreement index (Kappa) was often low. The most extreme case is the category "consistency" where almost all instances were annotated as "consistent" with perfect class specific agreement but low overall Kappa. In the case of utterance type and syntactic level where the distribution of instances across classes was more even, the general index of agreement Kappa is also high. In general, examples of conjunction showed little variability across annotation categories and mostly fell into one class within each category. Annotators had high agreement for these dominant classes.

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Table 11

Most prevalent annotation class in each annotation category with the values of class agreement indeces and category agreement indeces (Kappa).

Annotation Category	Class	Prevalence	Class Agreement Index	Kappa
intonation	flat	0.86	0.89	0.24
interpretation	AND	0.96	0.98	0.39
answer	NA	0.84	0.94	0.67
utterance_type	declarative	0.76	0.94	0.70
communicative_function	description	0.77	0.90	0.59
syntactic_level	clausal	0.67	0.91	0.70
consistency	consistent	0.99	1.00	0.50

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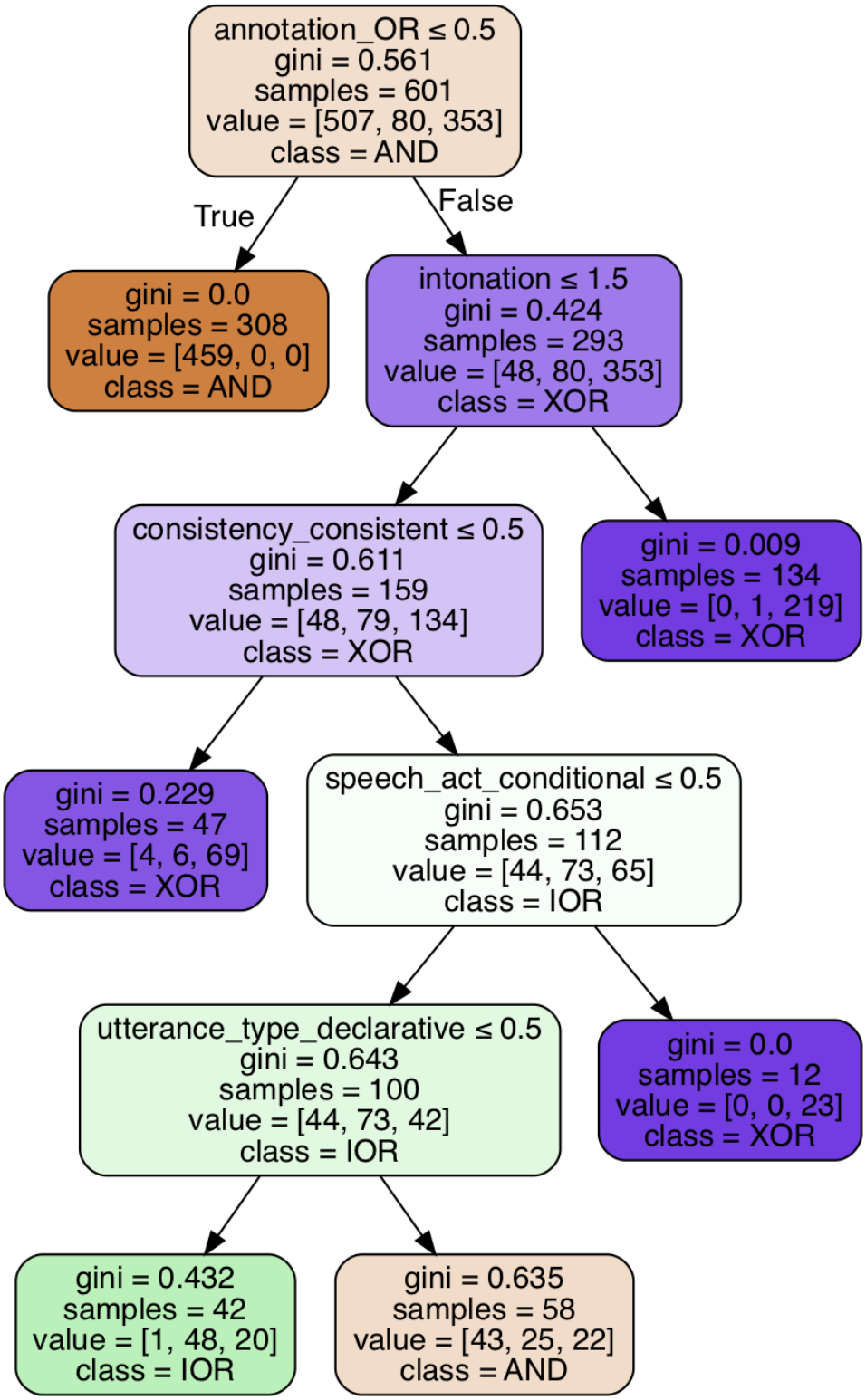

Figure 20. The cue-based tree grown on conjunctions and disjunctions with minimum impurity decrease of 0.01. After using the words *and/or*, the tree uses intonation, consistency,

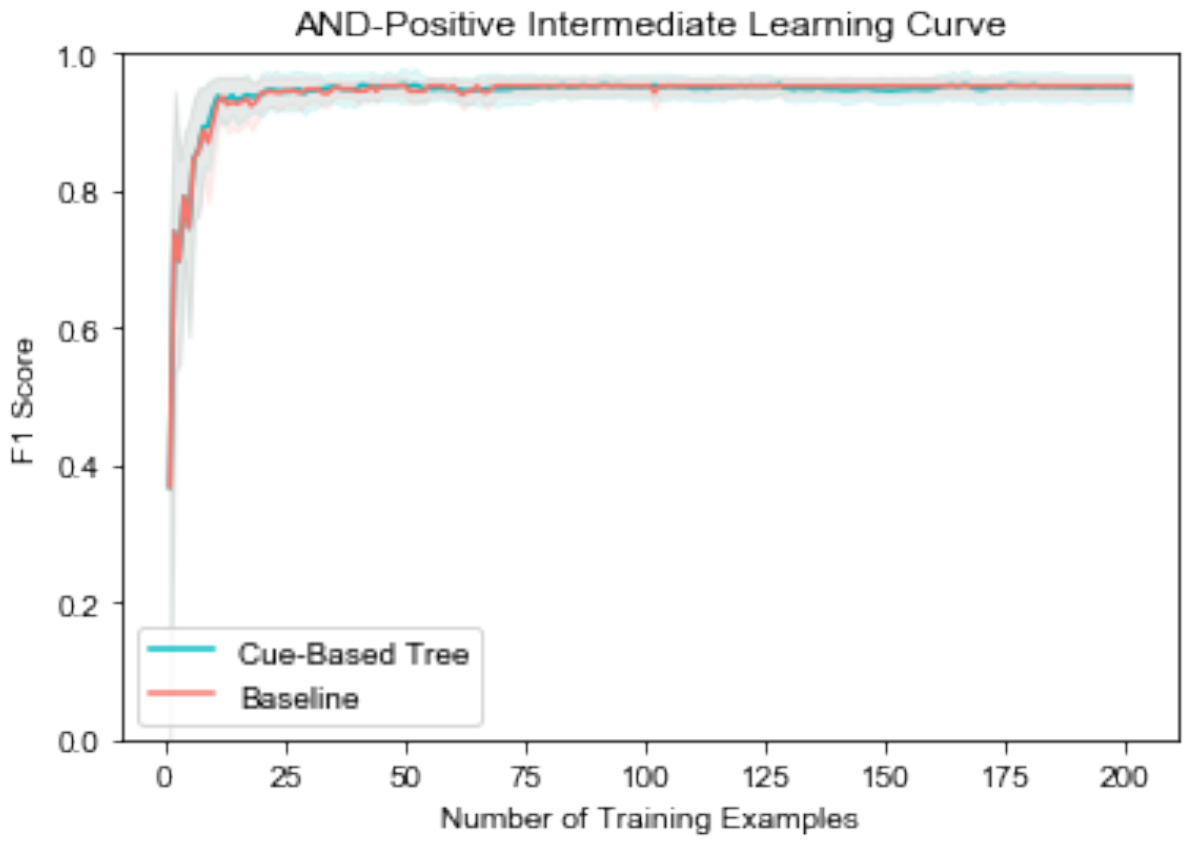

Figure 21. The average F1 score for class AND as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

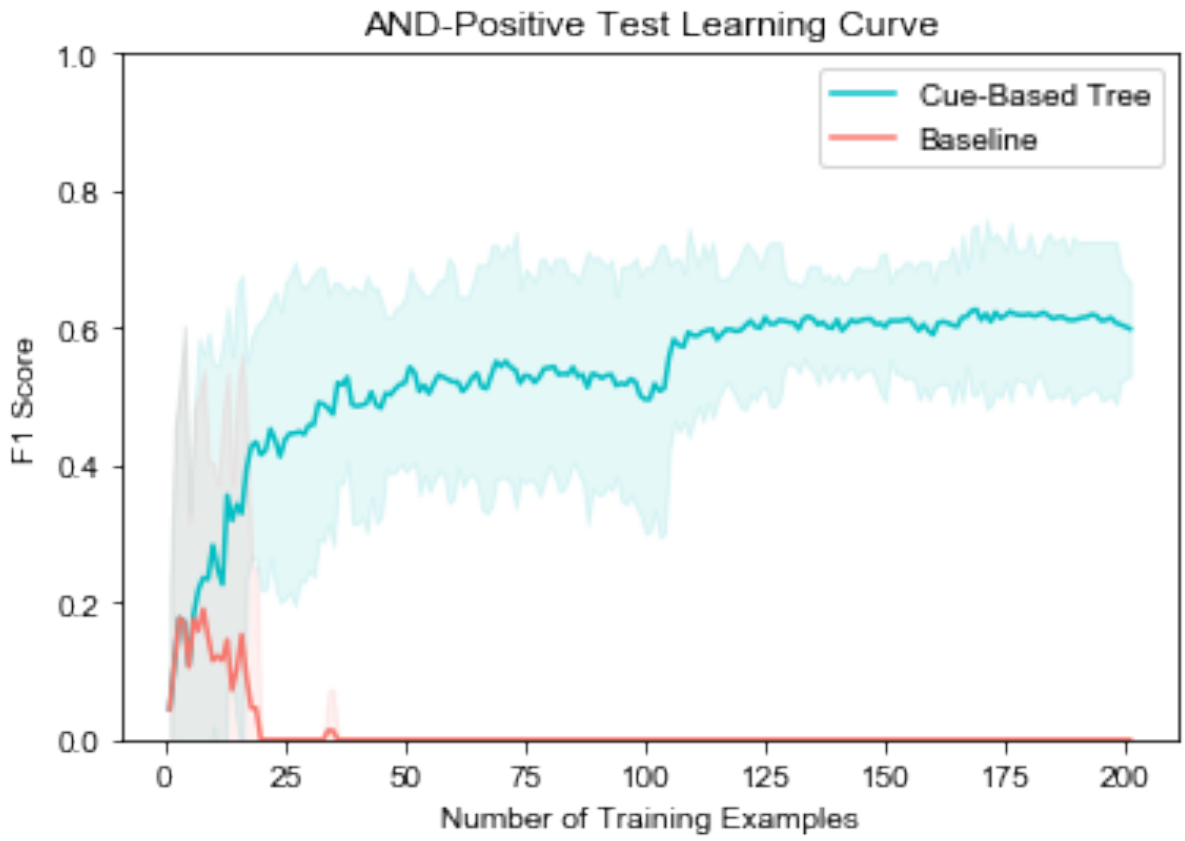

Figure 22. The average F1 score for class AND of disjunction examles as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

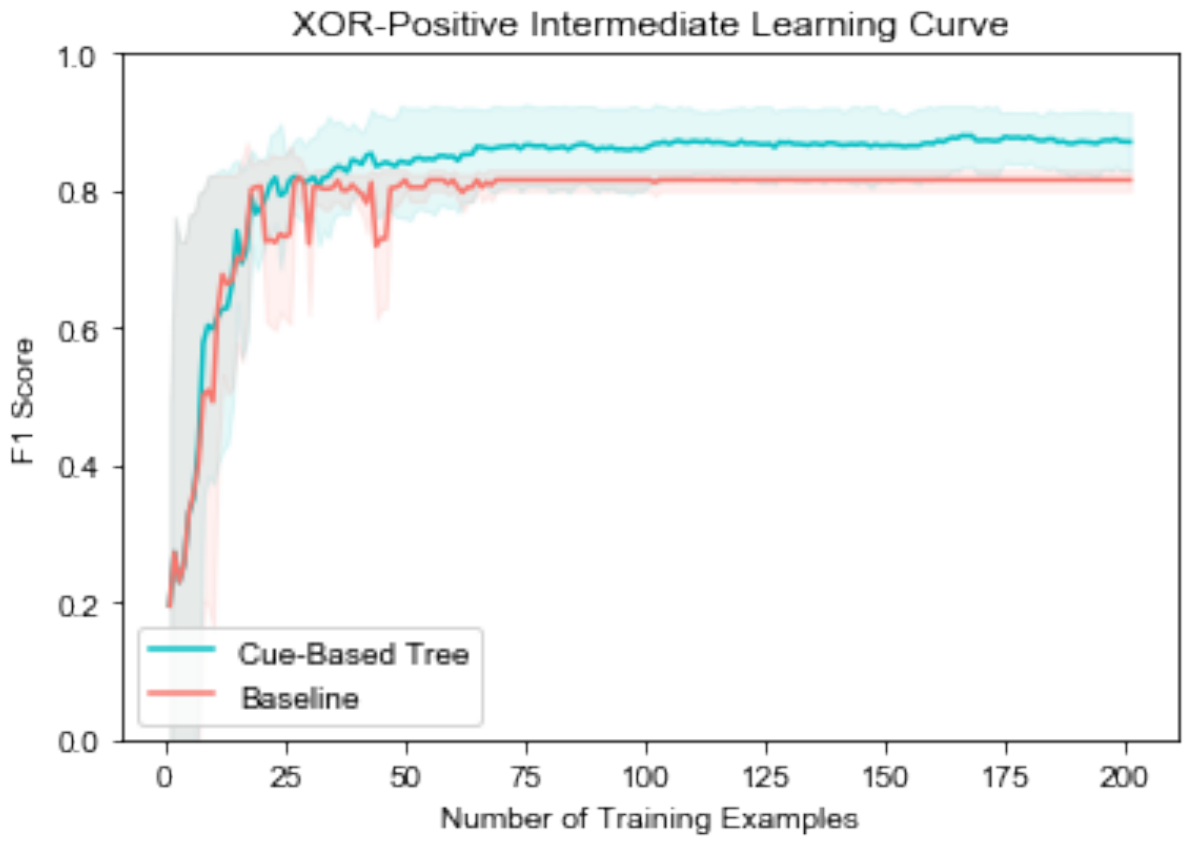

Figure 23. The average F1 score for class XOR as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

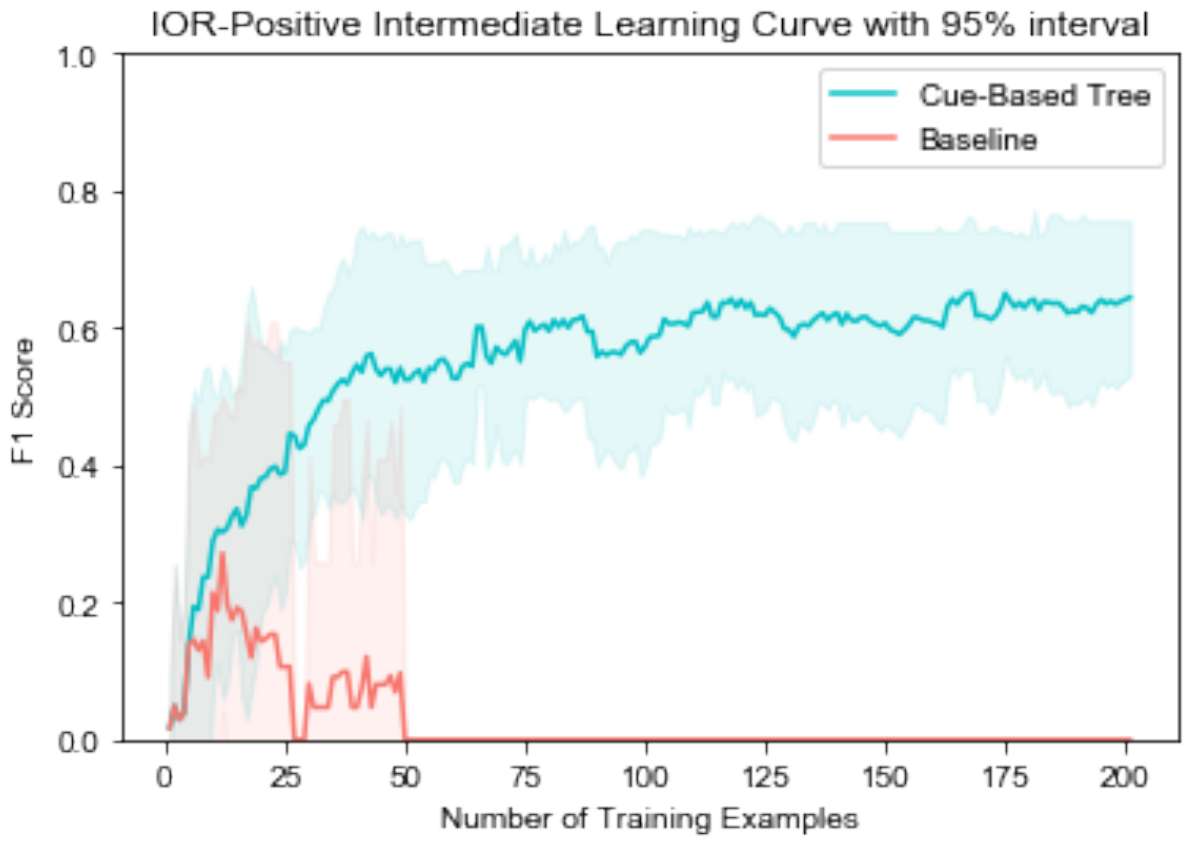

Figure 24. The average F1 score for class IOR as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

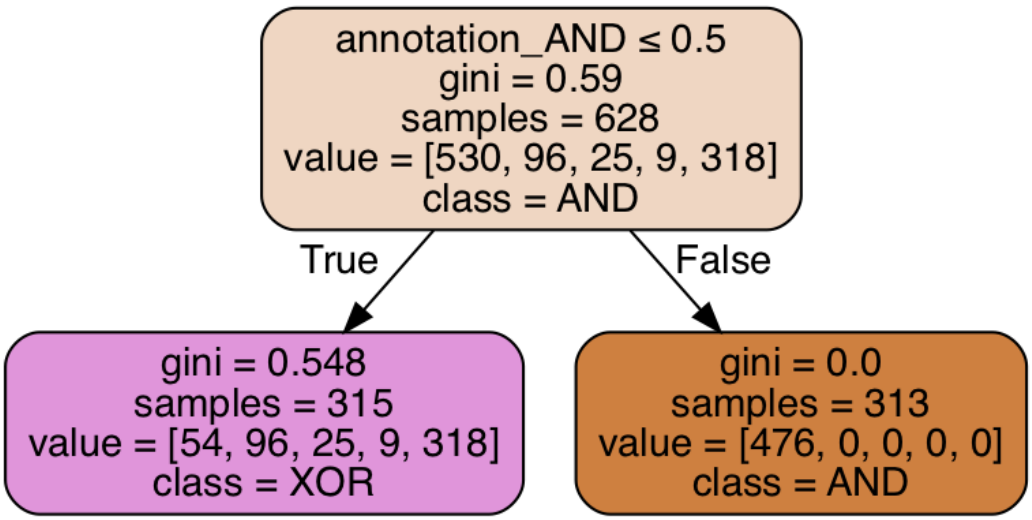

Figure 25. The baseline tree grown on conjunctions and disjunctions with minimum impurity decrease of 0.2. The tree uses the words *and/or* and classifies them as conjunction and exclusive disjunction.

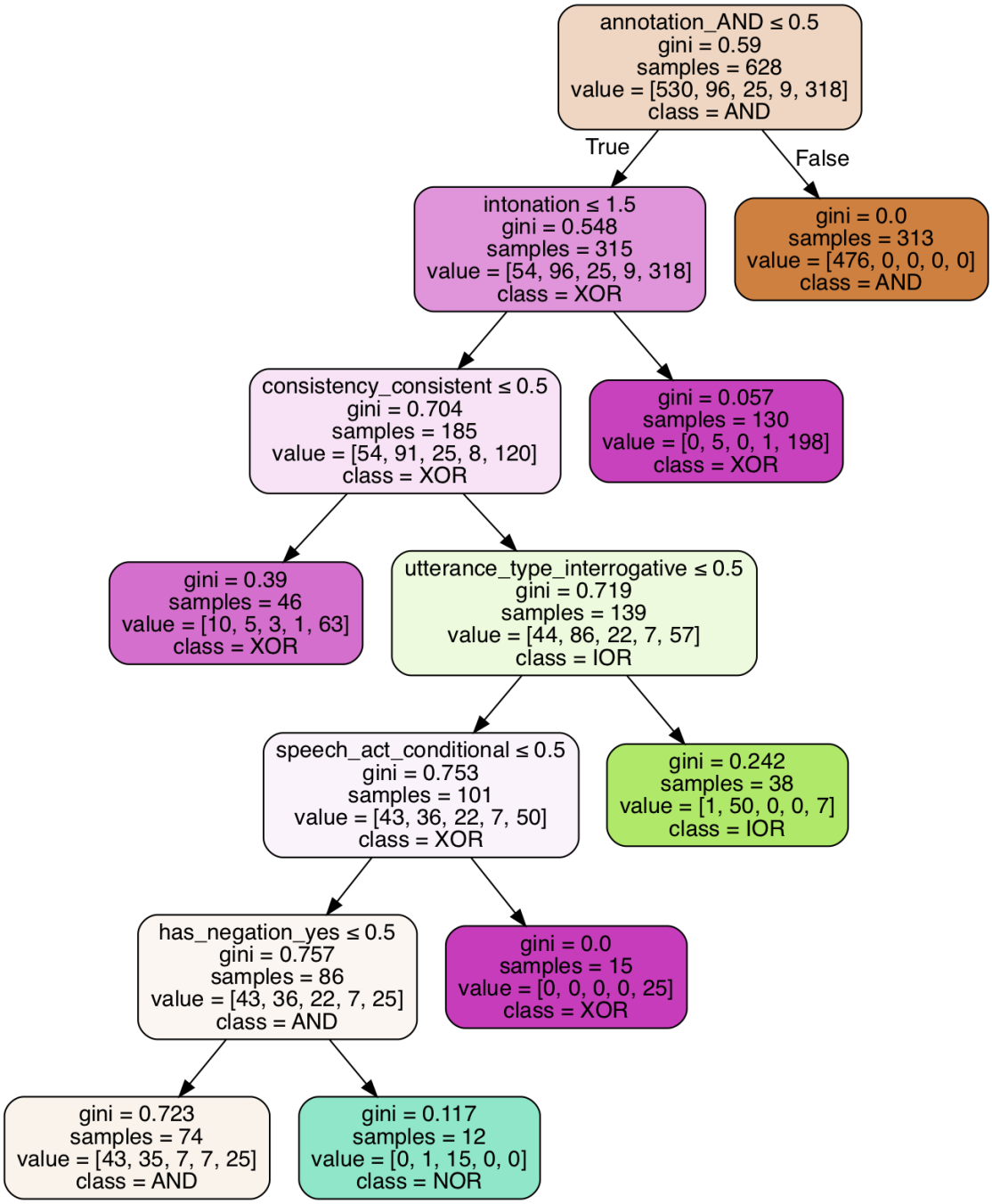

Figure 26. The cue-based tree grown on conjunctions and disjunctions with minimum impurity decrease of 0.01. After using the words *and/or*, the tree uses intonation and consistency to classify a large number of exclusive cases. Then it uses utterance type (interrogative) to label many inclusive cases, as well as the communicative function (conditional) to catch more exclusive examples. Finally, it asks whether the sentence has negation or not. If so, it classifies the negative inlusive examples as NOR.

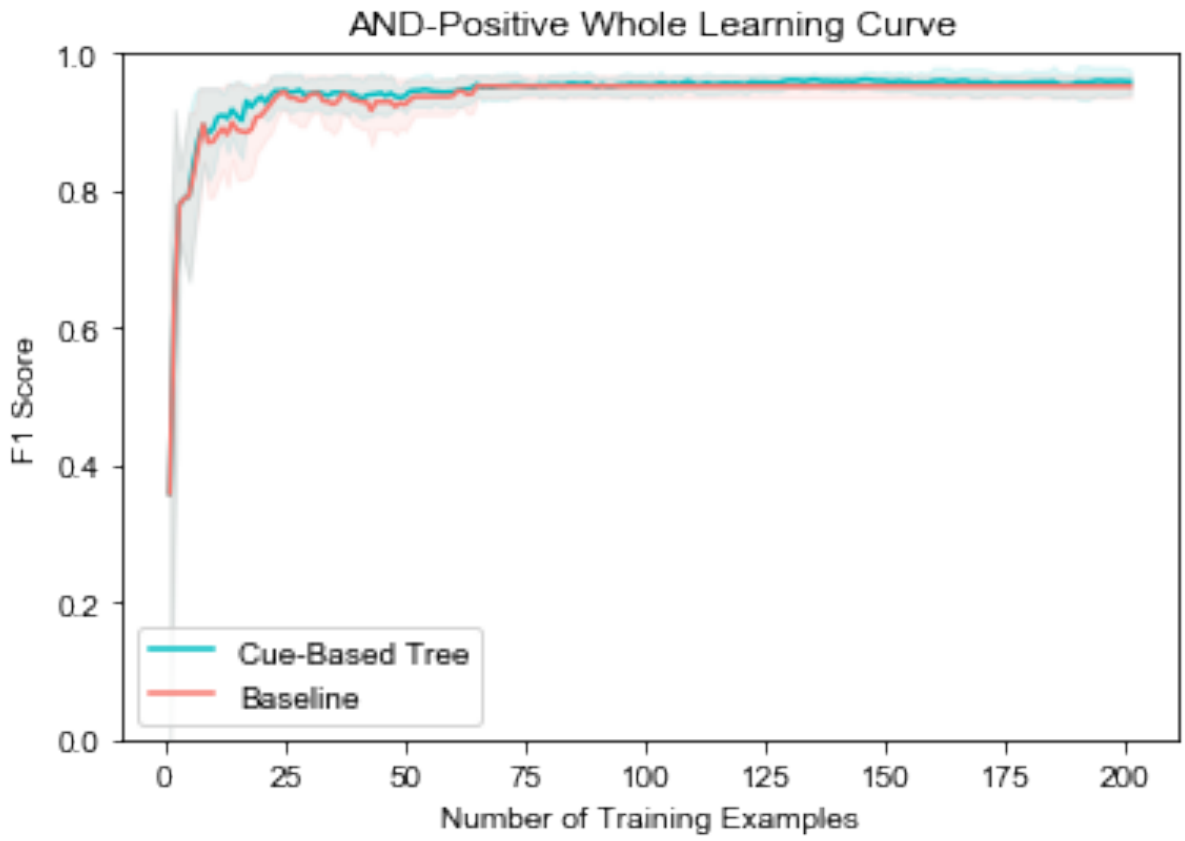

Figure 27. The average F1 score for class AND as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

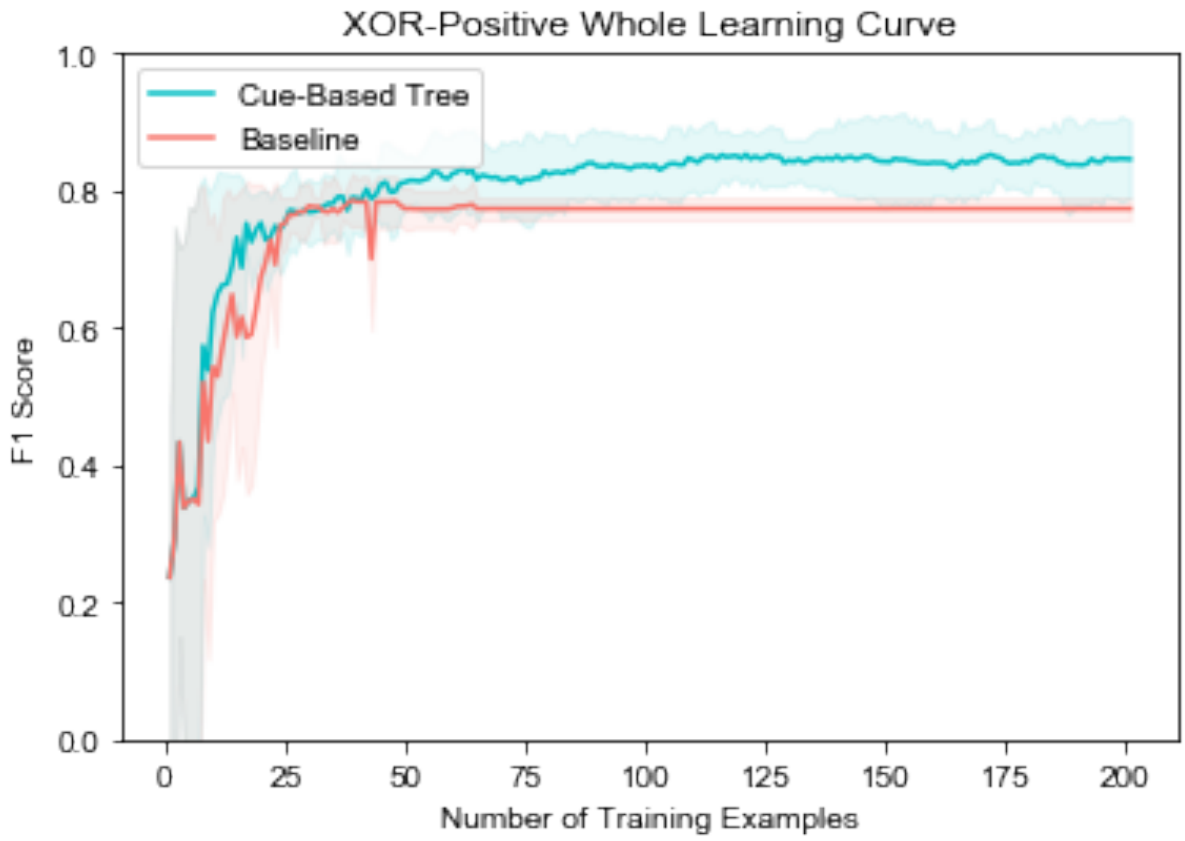

Figure 28. The average F1 score for class XOR as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

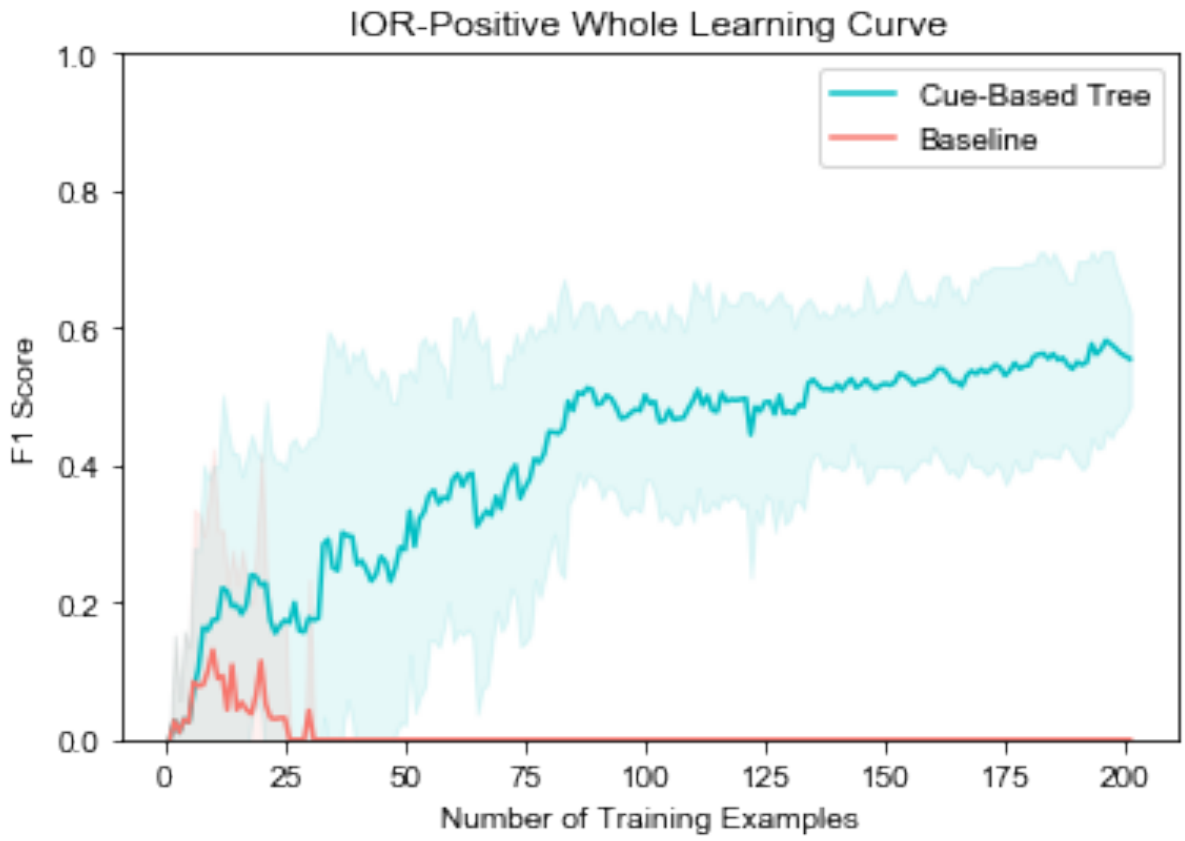

Figure 29. The average F1 score for class IOR as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

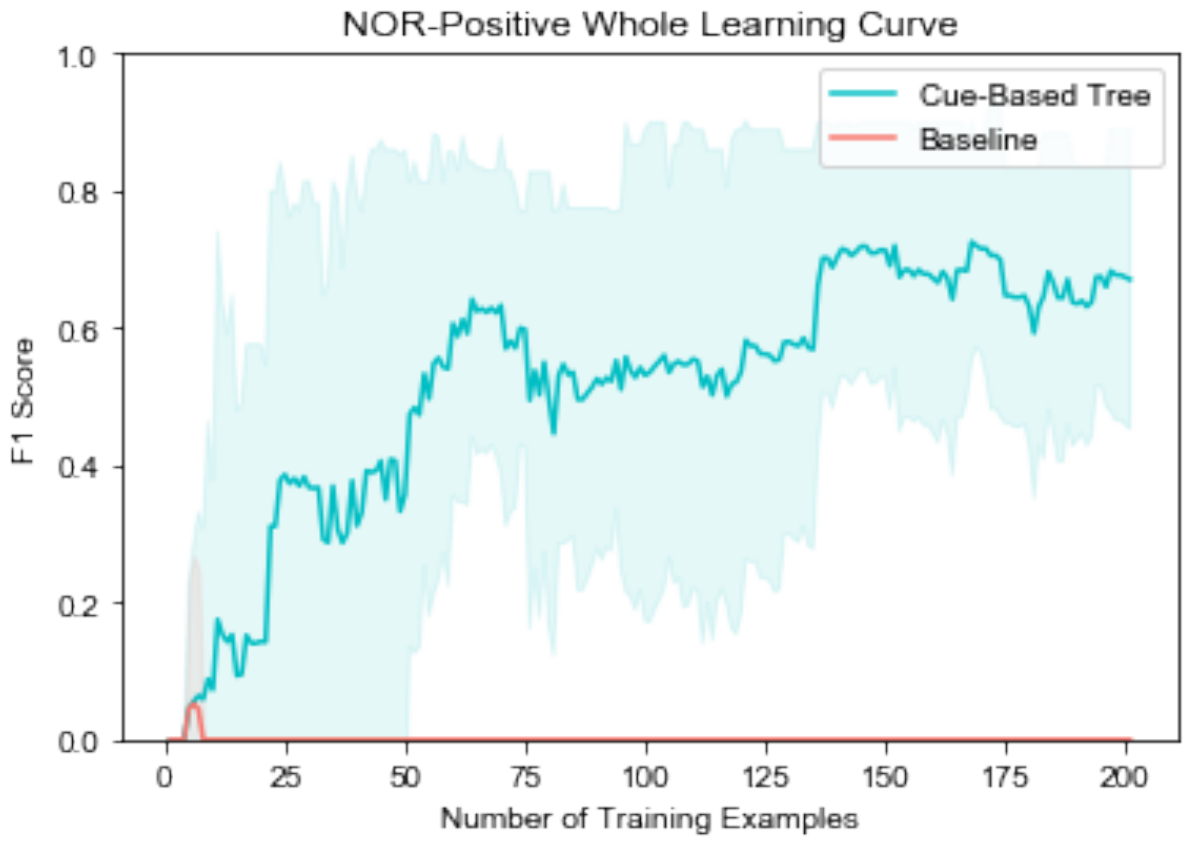

Figure 30. The average F1 score for class NOR as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

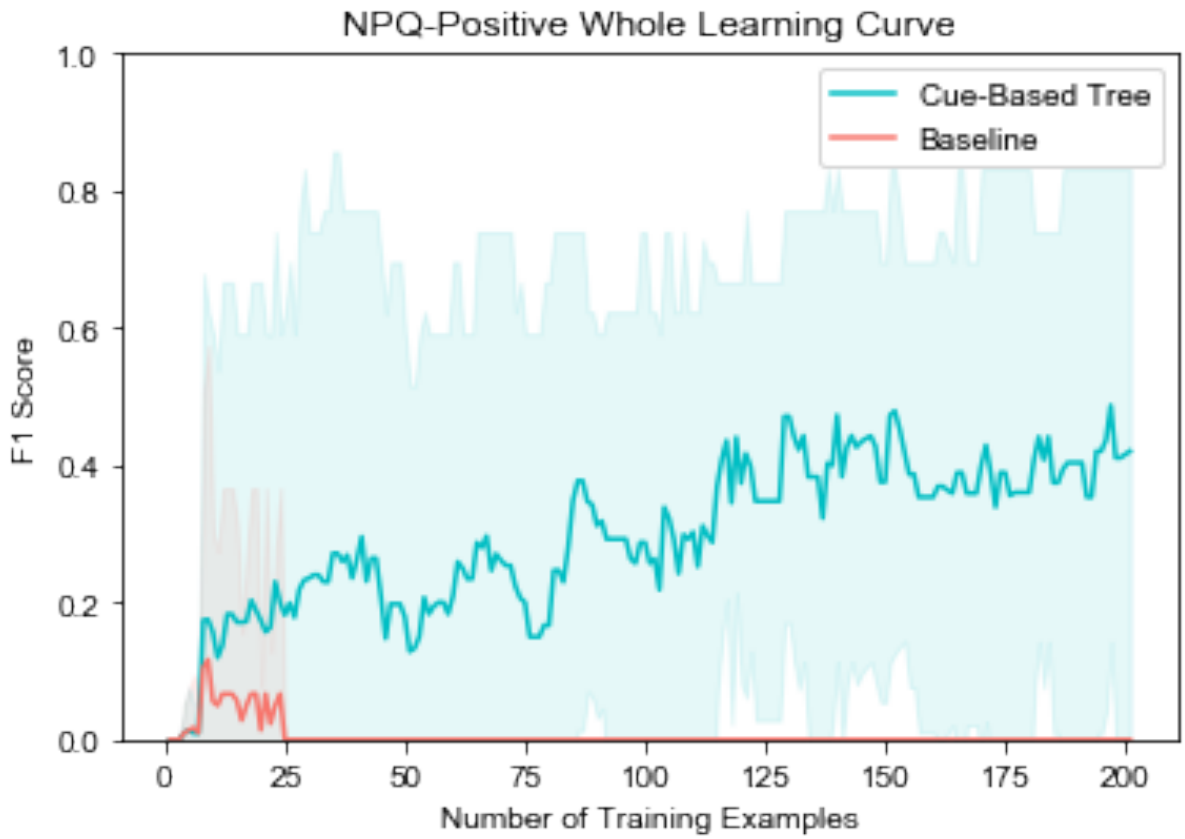

Figure 31. The average F1 score for class NPQ as a function of the number of training examples in the baseline and cue-based models. The colored shades show the 95% confidence intervals.

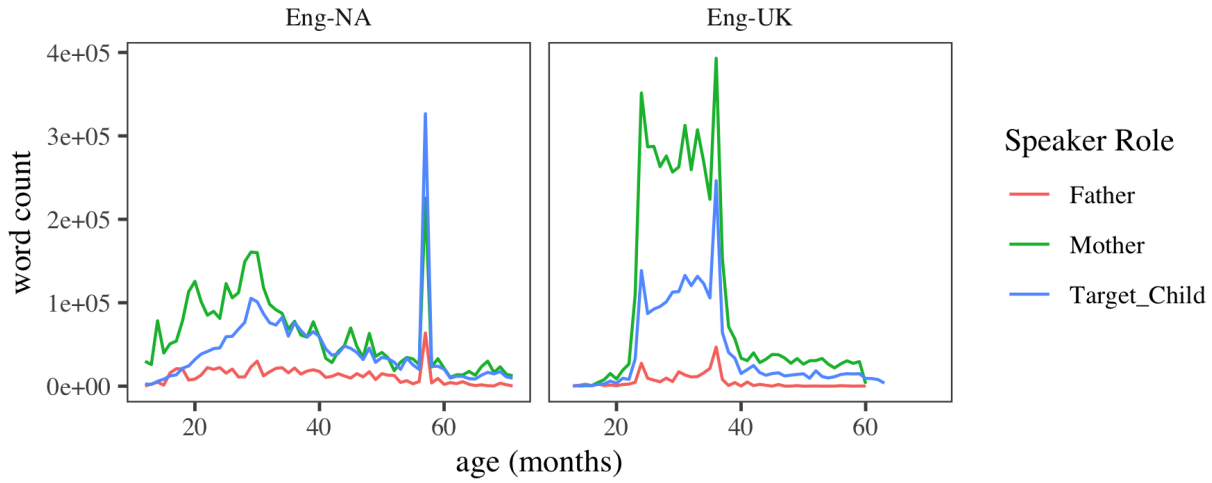

Figure 32. Frequency for all the words in the North America and UK corpora of CHILDES.

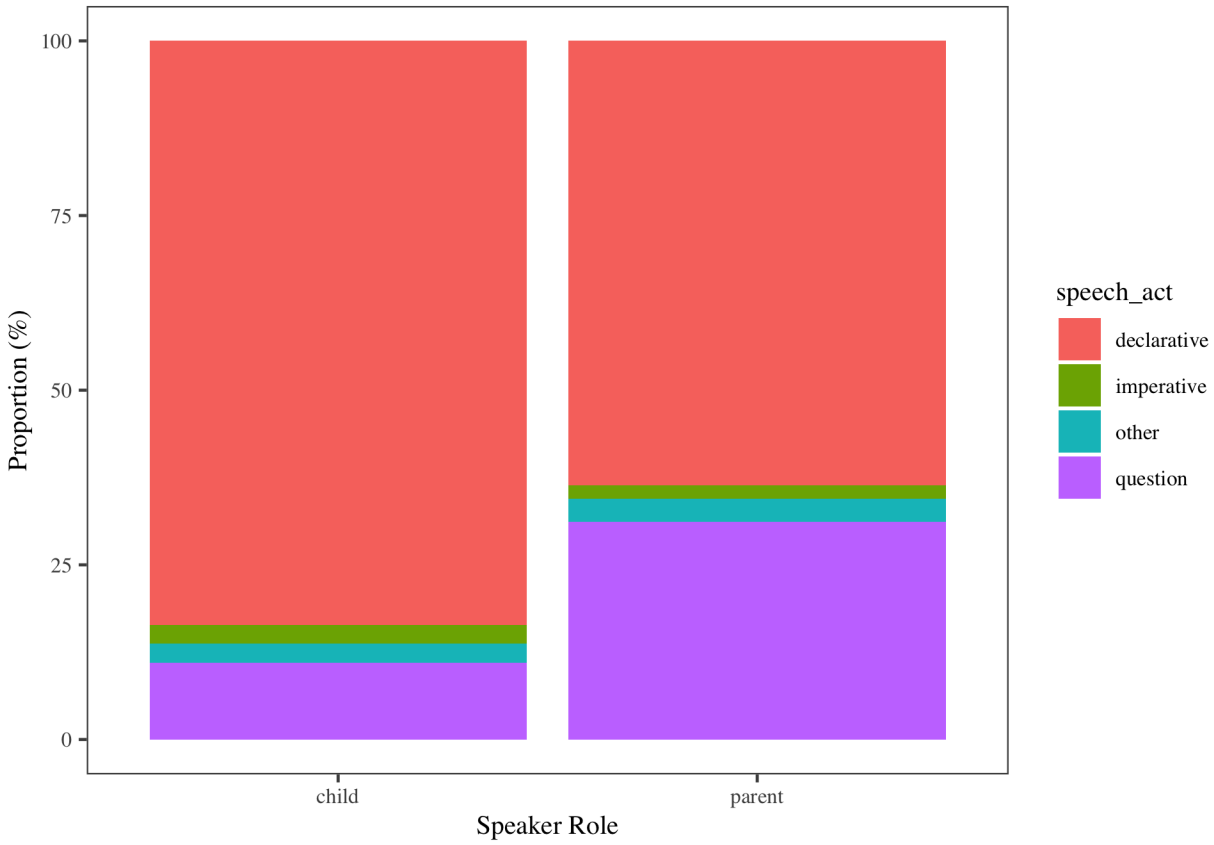

Figure 33. The proportion of declaratives and questions in children's and parents' utterances.

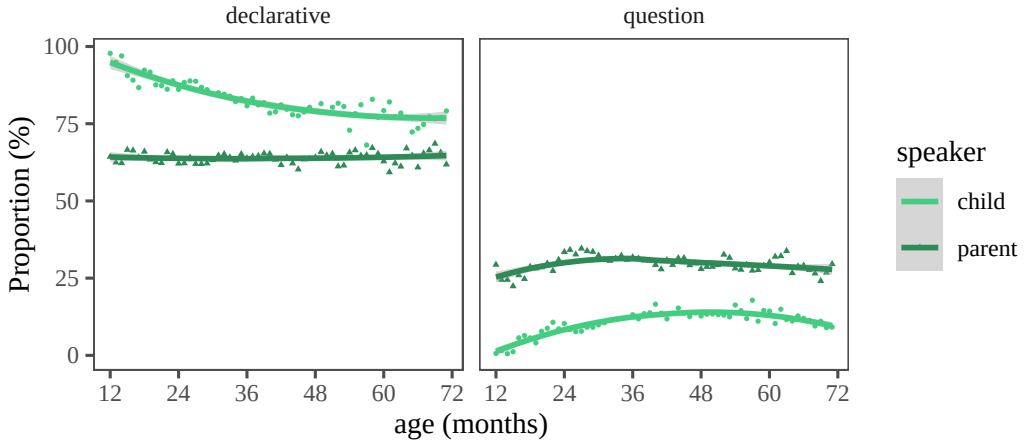

Figure 34. Proportion of declaratives to questions in parent-child interactions by age.

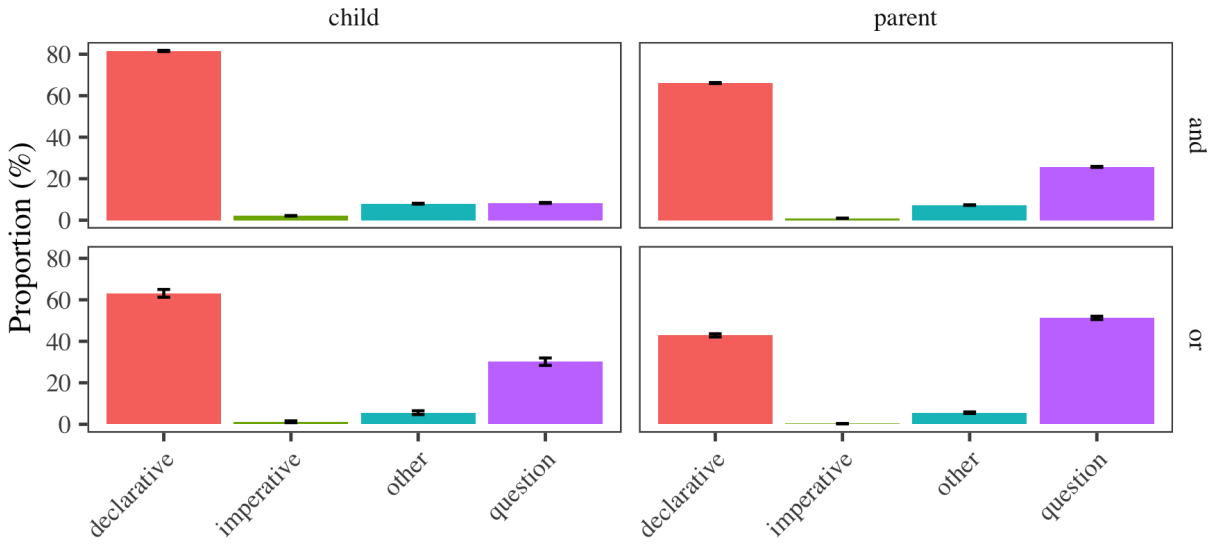

Figure 35. The proportion of *and* and *or* in different utterance types in the speech of parents and children.

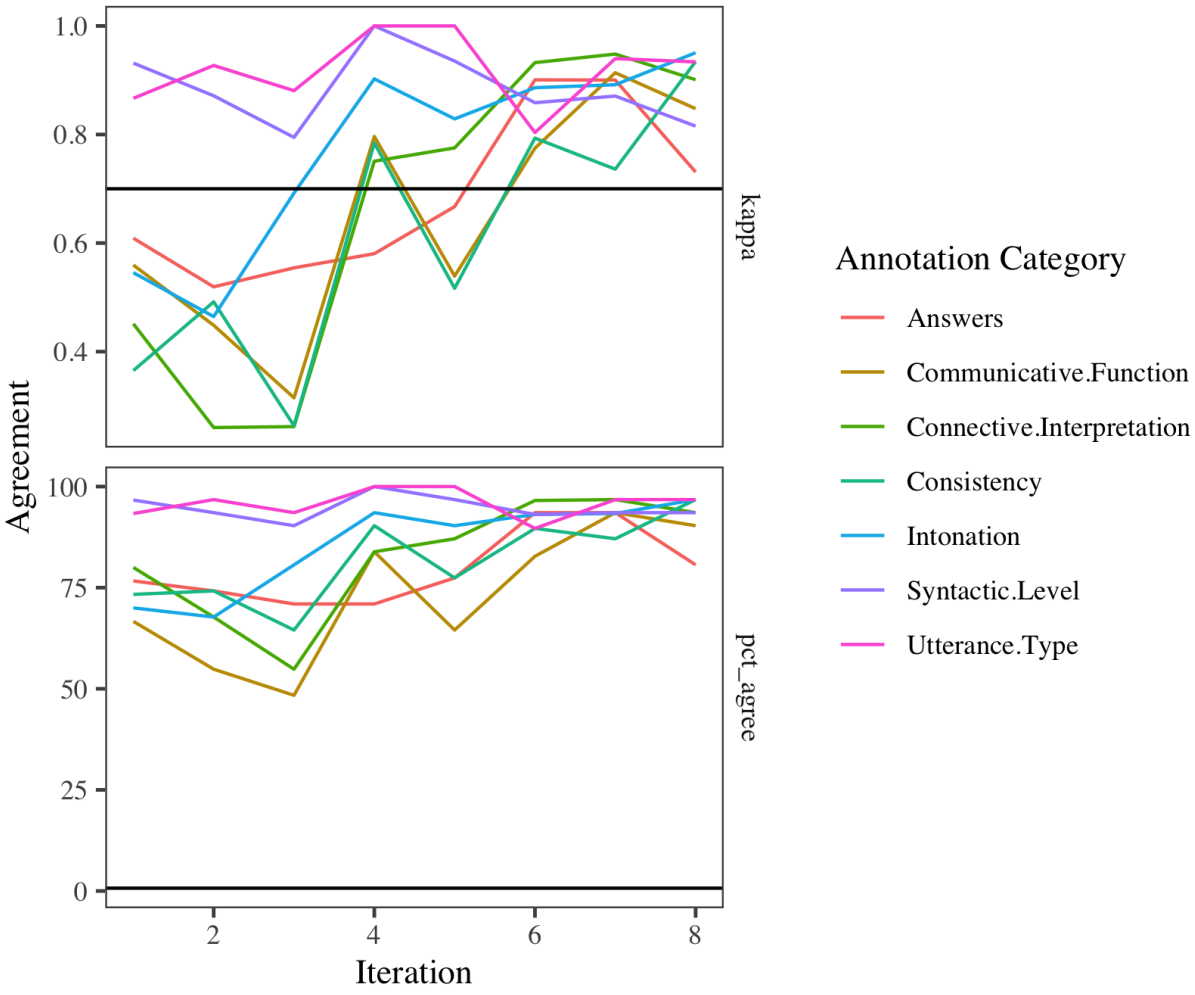

Figure 36. Inter-annotator agreement for disjunction examples.

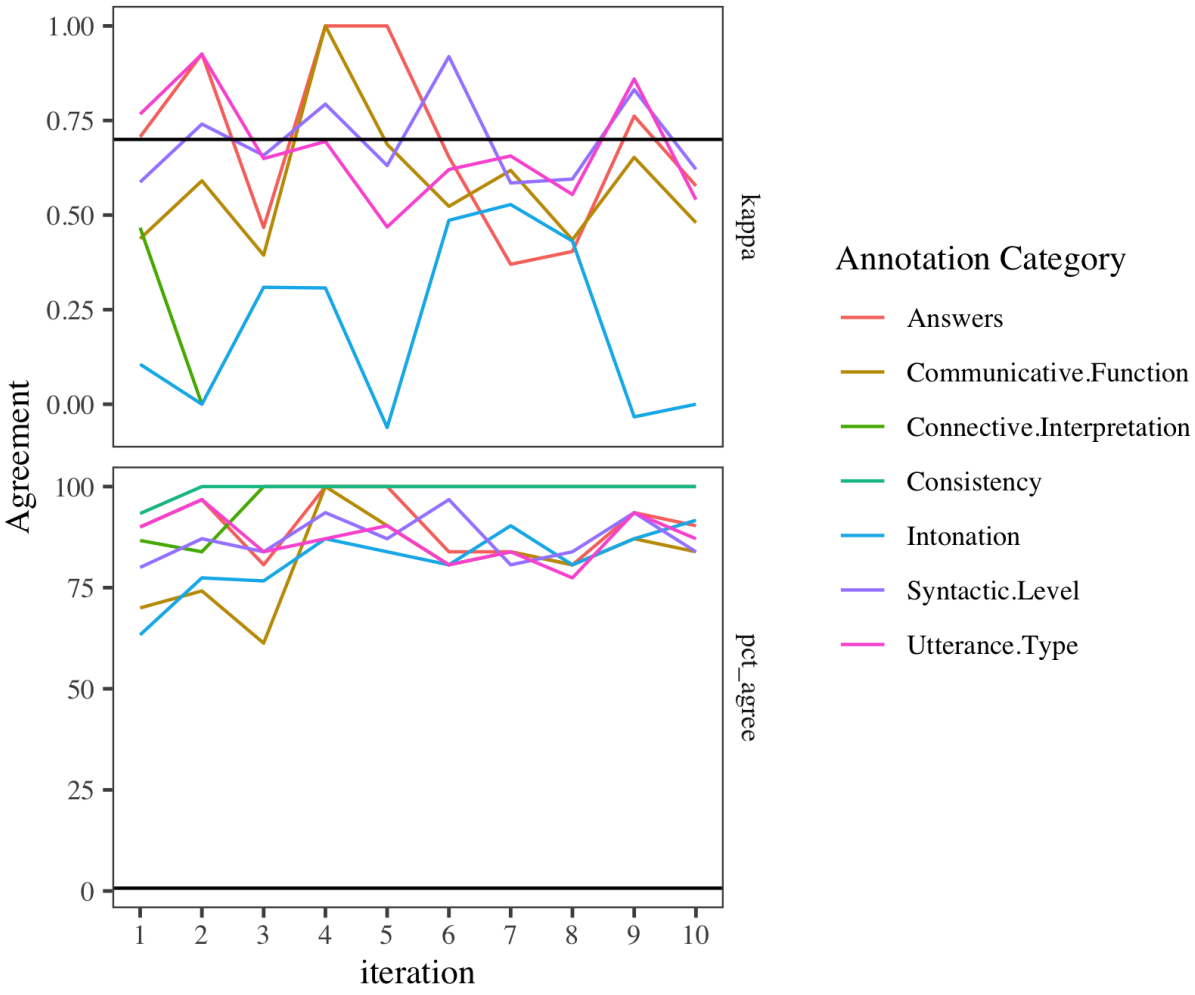

Figure 37. Inter-annotator agreement for conjunction examples.